HOLLOW TILE

AND

FIREPROOFING

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Hollow Tile and Fireproofing

Prepared Under Supervision of

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HOLLOW TILE

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FIREPROOFING OF BUILDINGS

By J. J. Cosgrove

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HOLLOW TILE

FIREPROOFING OF BUILDINGS

FIREPROOFING OF BUILDINGS—(*Continued*)

HOLLOW TILE

Serial 1834 Edition 1

ADVANTAGES AND NATURE OF HOLLOW TILE

1. Introduction.—Hollow terra-cotta blocks have been used for many years as a means of protecting the steel constructional parts of tall buildings from fire, as well as for constructing fireproof partitions, furring, etc. The employment of hollow terra-cotta blocks for the outside walls of buildings, particularly of residences, is more recent. Their use for this purpose is, however, quite extensive, and hollow-tile construction for walls of buildings has become thoroughly standardized. This style of construction is being used with increasing frequency where low-priced fireproof buildings are in demand.

2. Advantages of Hollow-Tile Construction. There are several advantages claimed for hollow-tile construction. Compared with wooden construction, it has the advantages that any masonry construction has over wooden construction; namely, greater stability, durability, and fire-resisting qualities, as well as a lower cost of maintenance. No matter how carefully a frame building is built and regardless of the excellence of the materials used and the high quality of the labor employed, its life is comparatively short. It must be kept in repair, and there is an increasing necessity for repairing as time goes on. Hollow-tile buildings, of course, also will need repairs, but the repairs necessary to keep a tile building in good condition are very much less than for a frame building. Hence, although the first cost of a building of hollow-tile con-

struction is greater than one of wooden construction, the ultimate cost, including cost of maintenance, when extended over a period of years, is less for the tile construction.

3. In the United States, where wood has been very plentiful and comparatively cheap, frame construction has flourished, but the enormous loss by fire in frame buildings is gradually leading to the erection of fireproof buildings of masonry.

Since tile is made of clay and has been thoroughly burned, it has fire-resisting qualities similar to those of brick, and buildings made of it can obtain low insurance rates.

For garages, hollow tile is one of the best materials that can be used, since it is not only economical and durable but possesses the most important requisite of any well-designed garage, that it shall be fireproof. It is not necessary to plaster the tile on the inside of a garage, as the wall can be made attractive by selecting tile with one face smooth or glazed and carefully pointing up the joints.

4. Another claim that is made for hollow tile is that it is sanitary and vermin proof, which makes it particularly adaptable for use in residences.

5. A further advantage of hollow-tile construction is that it is generally less expensive than any other form of masonry construction. This is an important consideration in the minds of architects and their clients. This economy in first cost is brought about partly by the nature of the hollow tile. Each tile is much larger than a brick and can be laid much more quickly than an equal volume of brickwork. A workman can, consequently, lay more cubic feet of wall with tile than he can with brick in a working day. The tiles are easily manipulated and can be broken and trimmed to fit peculiar conditions that are found when building walls.

Hollow-tile walls are strong and light in weight, which makes the load on the footings less than that of a solid brick wall. This saving in weight means an economy in the size and cost of the footings.

6. Another advantage claimed for hollow-tile construction is that the walls and floors are hollow. Each block of hollow tile consists of a sort of clay box divided by interior webs or partitions so that a wall built of hollow tile is honeycombed with holes. These holes, or cells, are excellent in many ways. For instance, the dead air contained within these cells provides excellent insulation against temperature changes, so that a hollow-tile wall is usually warmer in winter and cooler in summer than a wall of solid masonry. These cells also prevent the penetration of water through the walls.

7. It is claimed that interior plastering can be safely applied directly to the hollow-tile blocks, thus saving the cost of furring and lathing. It is not considered good practice to plaster directly upon the inner surface of a solid brick or stone wall, as dampness often works its way through and is apt to stain the surface of the plaster and to destroy decorations or papers that may be applied to the plaster.

8. Walls of hollow tile are easily arranged to contain heating and plumbing pipes as well as electric wires and conduits, either by building chases in the wall in advance of the installation of the pipes or by placing the pipes first and building the blocks around them. A common method, when the cells are set vertically, is to break slots or chases in the completed wall when it is time to run the pipes. This is easily accomplished, as the webs are quite thin and can be broken by sharp blows of a hammer and chisel. Care must be exercised, of course, in breaking into the finished wall to avoid damaging it too much.

9. Manufacture of Terra-Cotta Tile.—The manufacture of terra-cotta hollow tile is a comparatively simple process and consists, briefly, of kneading clay until it is of the proper consistency for molding, after which it is shaped into blocks and then baked in kilns.

10. Density of Terra-Cotta Tile.—Hollow terra-cotta tile is made in various densities, and three classes of the material are commonly recognized; namely, *dense, semiporous,*

and *porous*. These terms, however, are somewhat indefinite. For instance, when a kiln of tile is burned, the material closest to the fire is burned the hardest and consequently is dense, while the remainder of the tile in the same kiln might be classified as semiporous. Porous tile is of a different composition, and when burned is filled with numerous air spaces which make this material light and porous.

Most of the tile now manufactured is of the semiporous class because semiporous tile has been found by experience to be the most satisfactory ware.

A frequent requirement of building codes regarding the density of tile is as follows: "Tile used for bearing walls shall not have more than 12 per cent. absorption." That is, the tile when immersed in water shall not absorb more than 12 per cent. of its weight of water.

11. Dense Tile.—Dense tile, being burned the most, is therefore hardest and strongest, and is used where heavy loads are to be supported. It is used where walls are to be veneered with brick or where the tile is exposed to the weather. Unless the surface is scored, or grooved, plastering will not adhere to the surface of dense tile.

12. Semiporous Tile.—Semiporous tile is the kind most used in houses and small buildings. Tile of this class is sufficiently hard burned to be fairly impervious to moisture and to make good substantial walls, but not too dense to prevent plaster adhering to it strongly. The tiles are, nevertheless, generally scored or grooved so as to afford a good bond for plaster or mortar.

13. Porous Tile.—Porous tile is rarely used and should never be employed for any purpose except for building inside walls, or partitions.

14. Glazed Tile.—Tile for certain purposes is sometimes glazed. Glazing is done by introducing a quantity of common salt into the kiln when the material is nearly burned and this produces a glass-like film over the entire exposed surface of

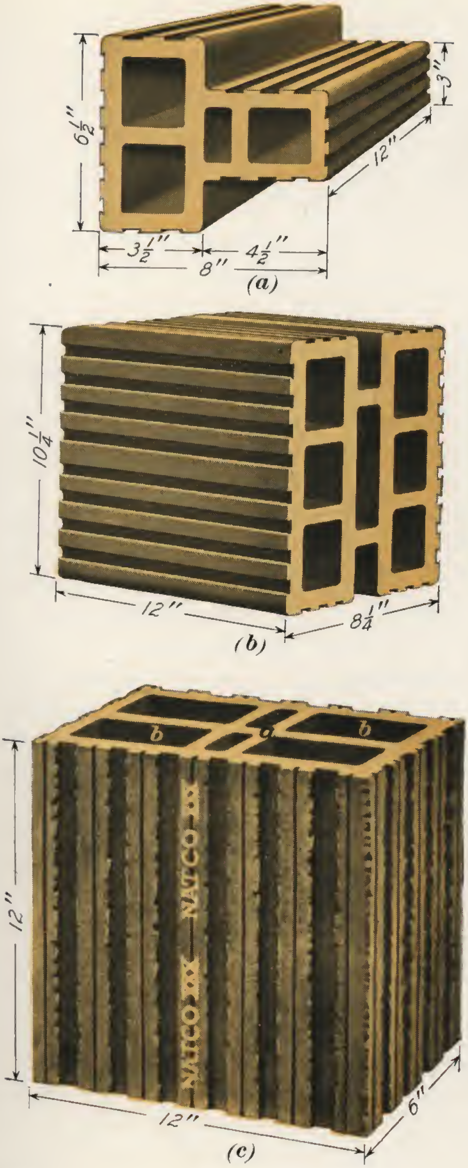

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Fig. 1

the tile. This tile must be grooved if it is to be plastered, as plaster or mortar will not adhere strongly to a glazed surface.

15. Vitrified terra cotta is generally made of fireclay or shale and is burned at a high temperature so that the material begins to fuse and is extremely hard throughout. This form of terra cotta is the densest kind, and is used for silos and other buildings in which the surface of the tile is exposed directly to the weather.

SHAPES AND KINDS OF HOLLOW TILE

16. Forms of Hollow Tile.—Hollow tiles used for the erection of the walls of buildings are made in three different general forms. These forms are shown in Fig. 1. In (*a*) is a **T**-shaped tile, known as an *interlocking tile;* in (*b*) an **H**-shaped tile, known as a *load-bearing tile;* and in (*c*) a regular, or box-shaped, tile. All these forms consist of units of burnt clay having outer shells and thin partitions, or *webs,* which divide the blocks into *cells.* These webs are shown at *a,* and the cells at *b* in (*c*). The shells are about $\frac{3}{4}$ inch and the webs about $\frac{5}{8}$ inch in thickness.

REGULAR, OR BOX-SHAPED, TILE

17. Description of Regular Tile.—In Fig. 2 are shown illustrations of some of the forms in which regular tiles are made. The blocks shown at (*a*) and (*b*) are used for closers and face blocks, as will be shown later on. Those at (*c*) and (*d*) are for building straight walls of different thicknesses. The blocks shown at (*e*), (*f*), (*g*), and (*h*) are modified forms of these regular blocks and are manufactured by the National Fire Proofing Company. They are known by the name of *Natco* hollow tile. Fig. 1 (*c*) is an illustration of a standard Natco block, showing in detail the arrangement of webs and the dovetailed scorings which are designed to afford a good grip for mortar and stucco.

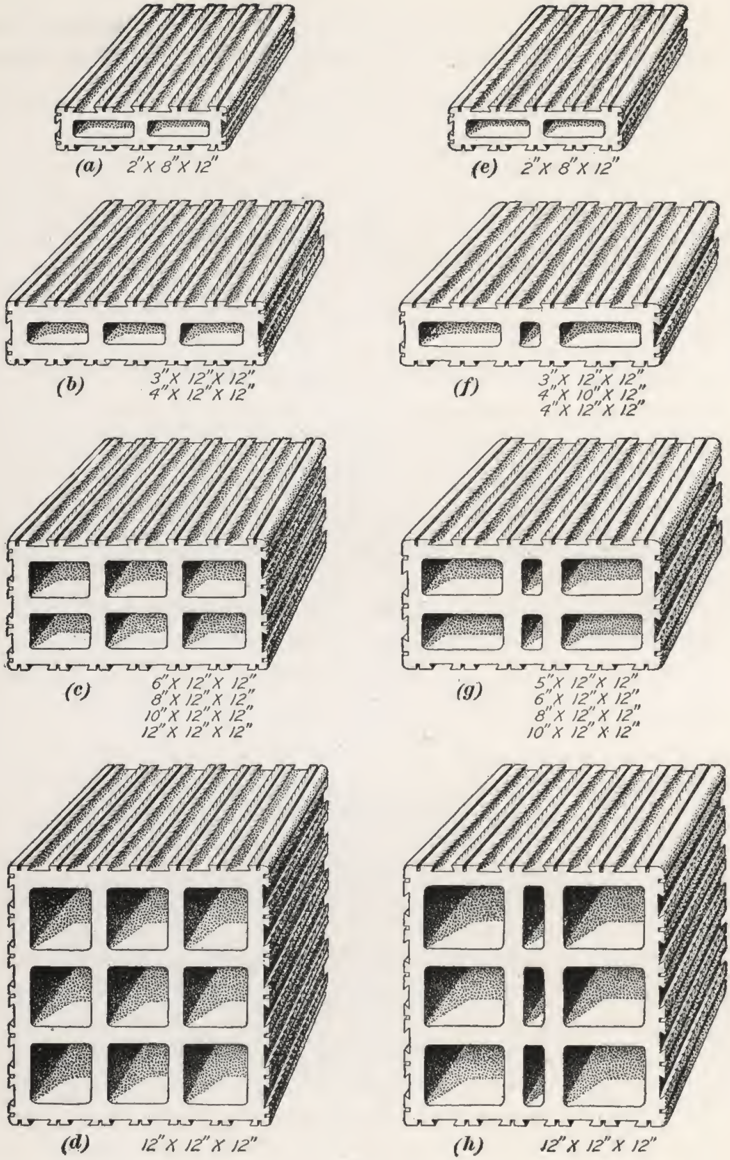

(a) 2"X 8"X 12"
(e) 2"X 8"X 12"
(b) 3"X 12"X 12"
4"X 12"X 12"
(f) 3"X 12"X 12"
4"X 10"X 12"
4"X 12"X 12"
(c) 6"X 12"X 12"
8"X 12"X 12"
10"X 12"X 12"
12"X 12"X 12"
(g) 5"X 12"X 12"
6"X 12"X 12"
8"X 12"X 12"
10"X 12"X 12"
(d) 12"X 12"X 12"
(h) 12"X 12"X 12"

FIG. 2

By special arrangement of the webs and cells which is shown in Fig. 1 (c) and in Fig. 2 (g) and (h), the webs of the block above always rest directly upon the webs of the block beneath

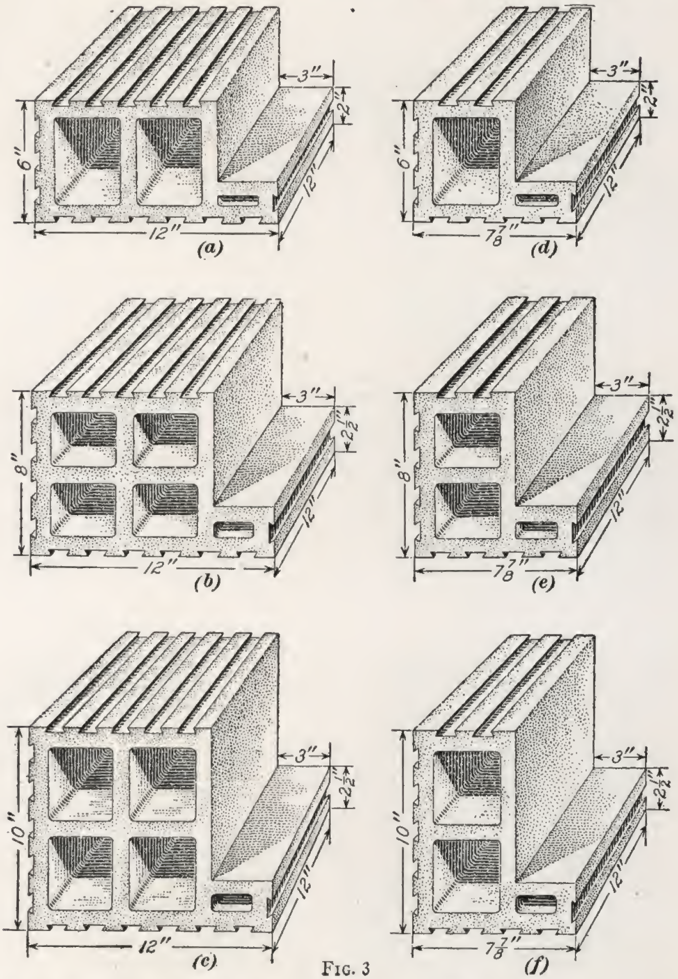


Fig. 3

when the joints are broken. The load on the tile is thus carried down to the ground by continuous webs of solid terra cotta. This also brings the cells into a continuous line from the top to the bottom of the wall so that they are available as pipe chases.

In Figs. 3 and 4 are shown jamb blocks and half jamb blocks, which are used for the jambs or sides of window open-

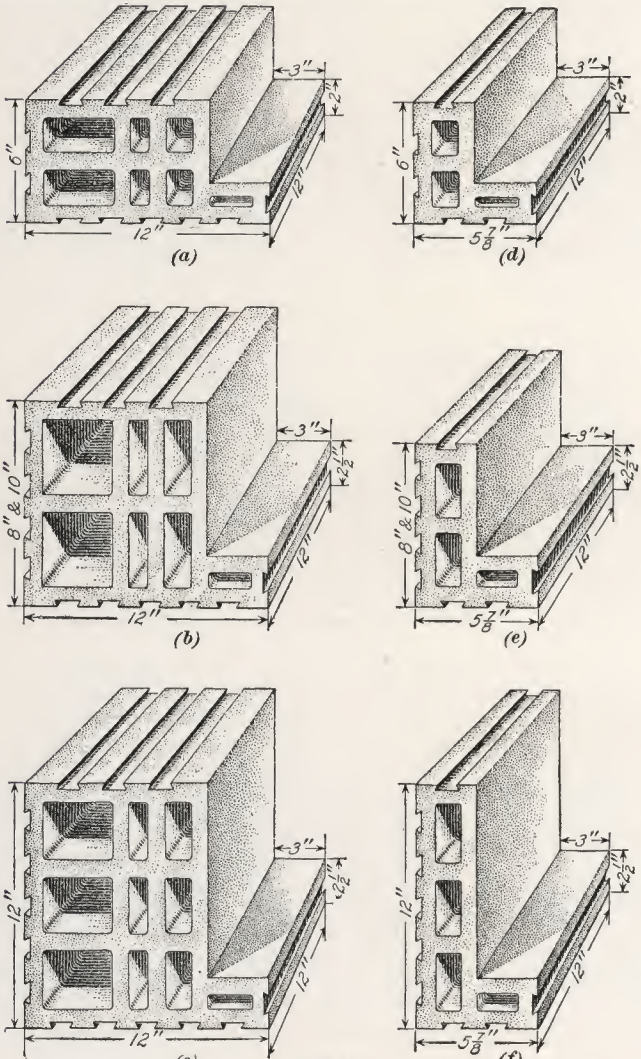


Fig. 4

ings when box window frames are used. In Fig. 3 are those that are used in connection with the regular blocks, and in Fig. 4

are similar blocks that are used in connection with the Natco blocks.

18. In Fig. 5 are shown box-shaped hollow tiles, made by the National Fire Proofing Company, which possess features that differ from those of the blocks already mentioned. For instance, these blocks are 5 inches in height instead of 12 inches and have double shells on the outer and inner faces

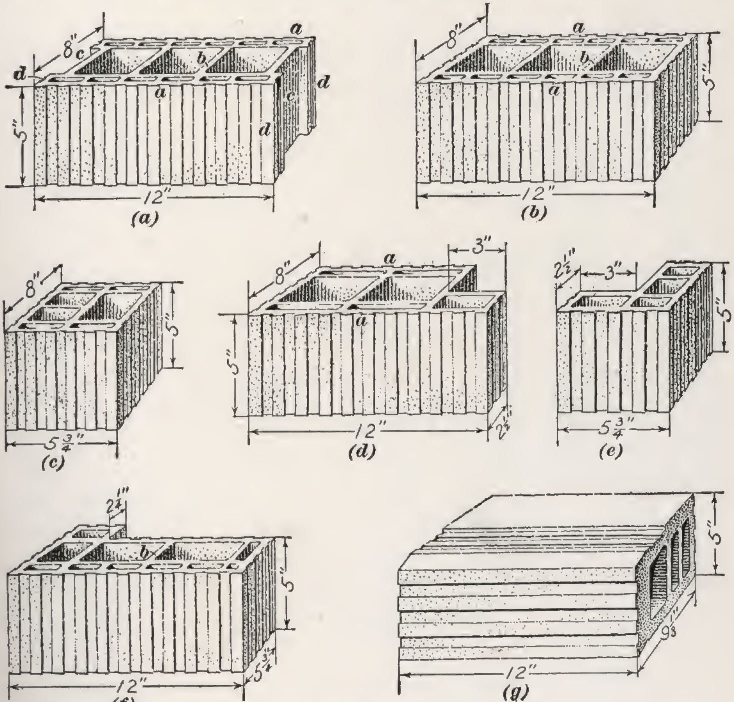


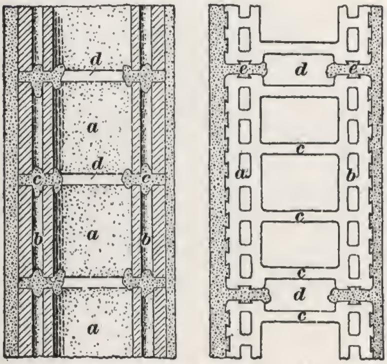
Fig. 5

of the principal blocks as shown at *a* in the different views in the figure. The cross webs *b* serve to tie the two faces *a*, *a* together, as shown in (*a*), rather than to support loads. Another feature that is different is the formation of the ends of the wall blocks (*a*). They are made with a hollow space *c* at each end so that the mortar joint does not extend through the wall but is placed on the surfaces *d* only. When the blocks

are set in place together this hollow space breaks the continuity of the mortar joint.

In Fig. 5 (*a*) is shown a standard wall block, in (*b*) and (*c*) *closure* tiles, or *closers,* for closing the ends of the cells in the tile at the end of a wall or at a door jamb. Jamb tiles and half jamb tiles are illustrated in (*d*) and (*e*), a corner block is shown in (*f*), and a sill block in (*g*).

Fig. 6 (*a*) shows a section taken vertically through several of these wall blocks, in which the double shells are at *b, b* and the webs at *a, a.* The mortar *c* is placed between the double shells only, and not between the webs at *d.* This breaks the continuity of these mortar joints. In (*b*) is a plan, in which the double shells are shown at *a* and *b* and the vertical webs at *c.* The air spaces between the ends of the blocks are at *d, d,* and the mortar joints between the ends of the tiles are at *e, e.*



(*a*) (*b*)

Fig. 6

19. The bulk of the wall, when regular tile is used, is composed of standard units, each consisting of a cellular block of tile, 8″ × 12″ × 12″ tile being used for an 8-inch wall, 10″ × 12″ × 12″ for a 10-inch wall, and 12″ × 12″ × 12″ for a 12-inch wall.

Units of different thicknesses are often used in the same structure, since it is often desirable to make the wall in one portion of a building thinner than in some other portion, the upper walls of a building often being made thinner than the lower ones.

20. Method of Setting.—The regular, or box-shaped, forms of tile are generally set with the webs and cells in a vertical position so that the edges of the blocks are over each other on the outside and inside faces of the wall. The blocks

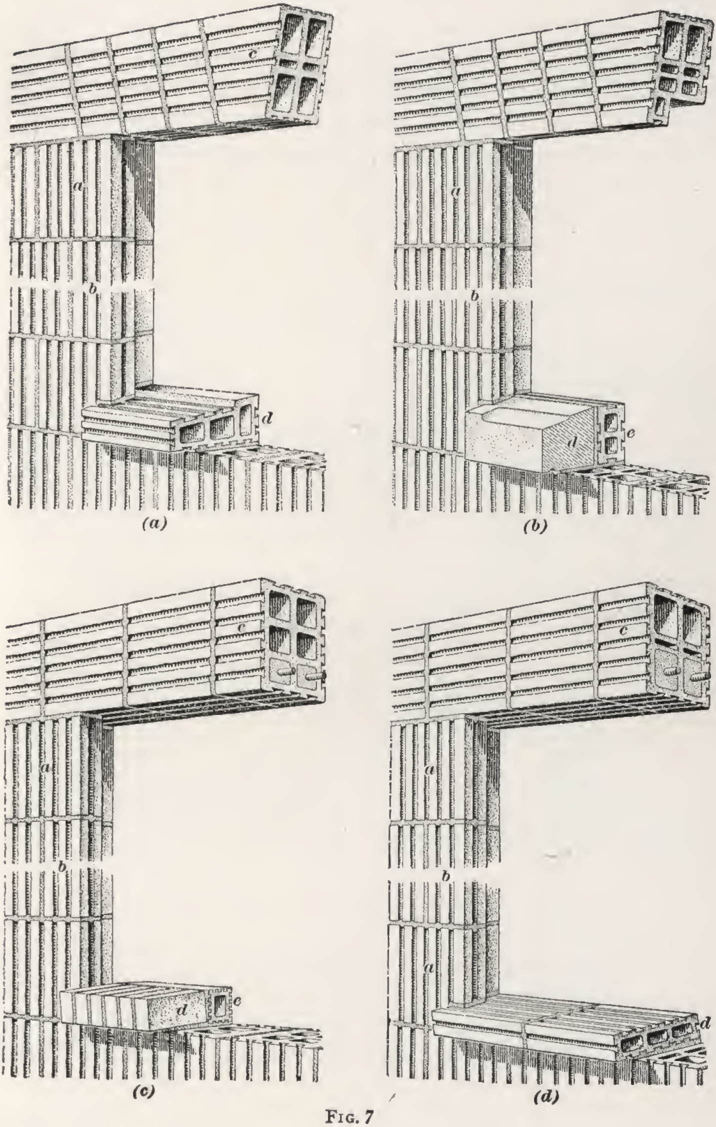


FIG. 7

are staggered over those below; that is, the vertical joint between two blocks is over the middle of the block below.

These tiles, set with the cells vertical, yield the maximum amount of strength. They are, however, sometimes set with the cells in a horizontal position, and for the ordinary loads that occur in dwellings, small factories, and other minor structures they are sufficiently strong when set that way.

21. The method of setting blocks with the cells vertical affords an easy means of forming chases for pipes and also allows of forming concrete piers beneath concentrated loads

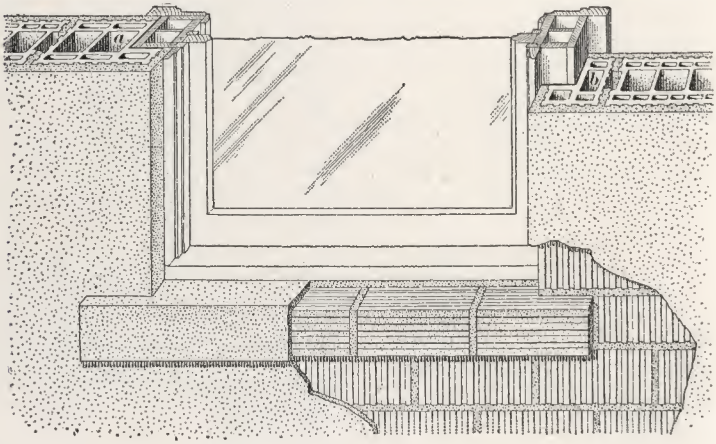


Fig. 8

that may occur in the structure. These concrete piers can be formed by simply filling a number of the cells below the special load with concrete, which sets and forms a strong vertical support, or pier.

Where the blocks are set with the cells in a horizontal position, it is difficult to cut chases and impossible to form special piers with concrete as just described. In such a case the chases must be formed as the wall is built, as will be described later.

22. Special Shapes.—There are several special shapes in hollow-tile blocks that are used in connection with the regu-

lar tile; some of these shapes are *jamb blocks, lintel blocks, sill blocks,* and *solid slabs.*

23. Jamb Blocks.—Jamb blocks, shown in Fig. 3, are used where box window frames are installed in a building. These blocks contain a rabbet into which the window frame is set. The use of jamb blocks and half jamb blocks is illustrated in Fig. 7, where at *a* are shown jamb blocks and at *b* half

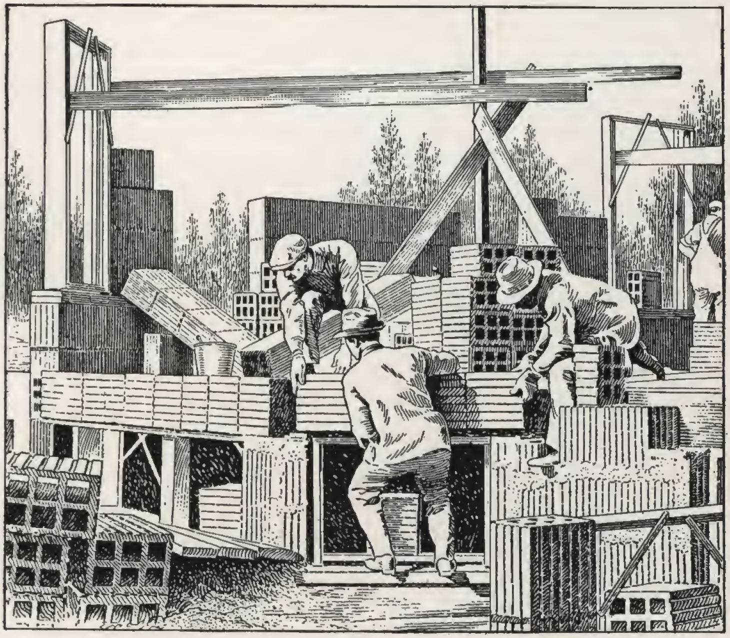


FIG. 9

jamb blocks, which are used alternately in the height of the wall in order that the wall blocks may break joints and also bond in strongly with the window jambs. Jamb blocks *a* and half jamb blocks *b,* for use in connection with the blocks shown in Fig. 5, are shown in Fig. 8.

24. Lintel Blocks.—Lintel blocks are used to form lintels over door and window openings that are not over 5 feet in width. One type of lintel block is made in the shape of a

voussoir or arch stone, so as to form a flat arch as shown in Fig. 7 (*a*). Another form of block, shown in (*b*), also forms a flat arch and has a rabbet *c* which is designed to receive the top of the window frame. The lintels most frequently used in practice are shown in (*c*) and (*d*), and consist of several standard blocks placed together as illustrated. These blocks are piled up on end, steel rods are placed in the cells that are to be the bottom ones when the lintel is in place, and these cells are filled with concrete or strong mortar. The rods extend throughout the entire lintel and provide tensile strength for the bottom of the lintel. When the concrete or mortar has thoroughly set, the lintel may be lifted and set in place in the same manner as a stone lintel, as illustrated in Fig. 9.

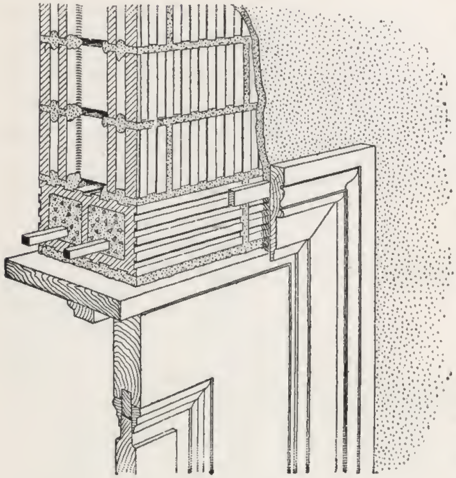


Fig. 10

A form of lintel used with the blocks shown in Fig. 5 is illustrated in Fig. 10.

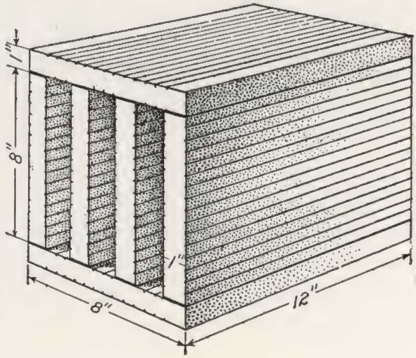


Fig. 11

25. Sill Blocks. — Tile for window sills can be obtained in the form shown at *d* in Fig. 7 (*a*). This sill is made with a suitable wash and rabbet, and is grooved to hold a stucco coating. Another form of sill is shown at *d* in (*d*) and con-

sists of standard tiles 2 inches or 3 inches thick and laid either flat or with a slight slope. This sill is also designed to receive a coating of stucco. Other sills are used in connection with hollow-tile construction, such as the stone sill shown at *d* in (*b*) and the brick sill *d* in (*c*). The sill in (*c*) may be constructed of hollow terra-cotta tile of brick size, or of ordinary brick and covered with stucco; or it may be formed of face brick and show the brick surface on the finished sill. Stone or brick sills are sometimes backed with terra-cotta blocks, as shown at *e* in (*b*) and (*c*).

26. Solid Slabs.—Solid slabs, 1 inch in thickness, are made for use under beams. They are laid over the cells on top of the regular wall blocks to form a continuous bearing for floorbeams, as shown later. These slabs are delivered at the building in the form of boxes resembling the regular box tile, as shown in Fig. 11. When tapped on the corner, these blocks fall apart into 6 flat slabs. The sizes in which these slabs are made are 1 in. × 8 in. × 10 in.; 1 in. × 6 in. × 12 in.; and 1 in. × 8 in. × 12 in.

T-SHAPED TILE

27. Form and Use.—As indicated by the name, **T**-shaped tiles have a shape similar to that of the capital letter **T**, as is shown in Fig. 1 (*a*) and also in Fig. 12. This type of tile is laid with the cells in a horizontal position.

The particular advantages claimed for the **T**-shaped tile are, first, that the shape of the tile breaks the direct mortar joint between the outside and inside surfaces of the wall. This will be seen in Fig. 12, where in (*a*) is shown an 8-inch wall, in (*b*) a 12-inch wall, and in (*c*) a 16-inch wall. In all these walls it will be seen that the mortar joints *a* are interrupted by the air spaces *b*, so that moisture cannot penetrate through the wall by way of the mortar joints.

The second advantage claimed is that no air space in one course of tile communicates with air spaces in the next course above or below, hence there is less circulation of air than when the cells are placed vertically.

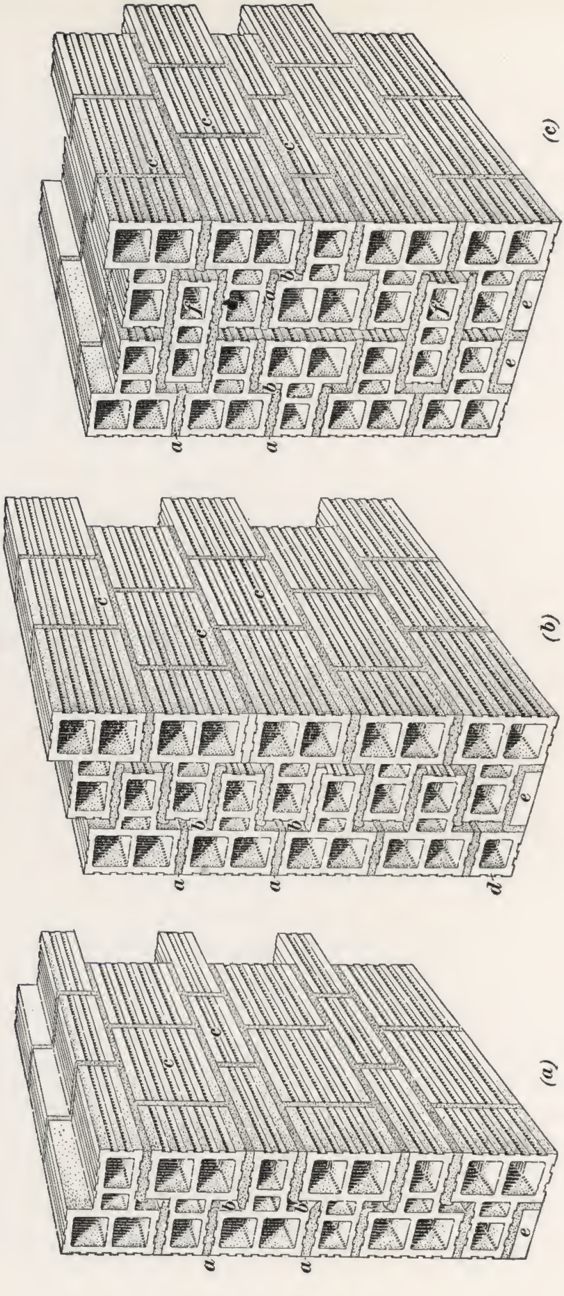
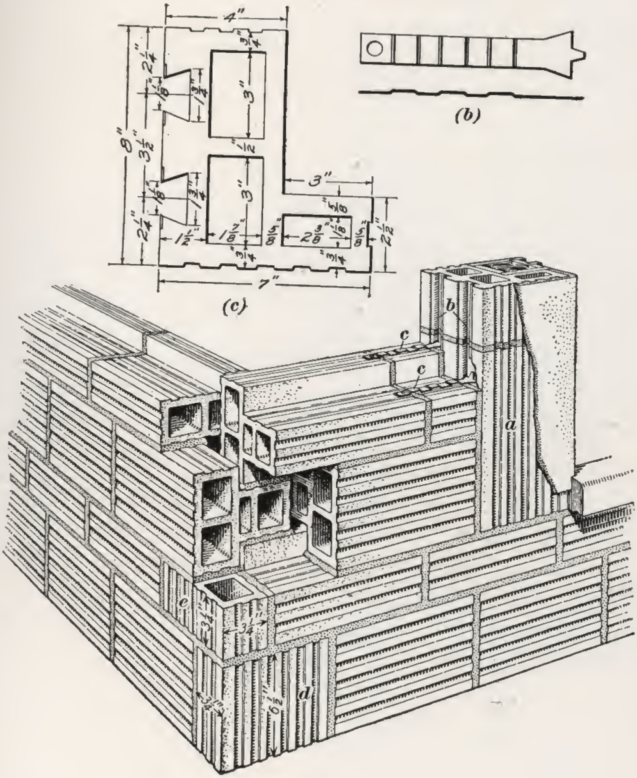


Fig. 12

As in the regular tile, the webs come directly over each other, thus forming continuous webs that carry down the loads supported by the wall to the footings under the wall.

In laying these blocks, the joints are staggered or broken, as shown at *c*, as is done in laying the regular blocks. In Fig. 1



(a)

Fig. 13

(*a*) is shown a **T** tile with the standard dimensions. The standard tile is 12 inches in length, but some of the blocks are scored or indented so that they can be easily broken into 4-inch and 8-inch lengths when desired. This does away with the necessity of purchasing extra shapes for places in the wall where these shorter lengths are required.

28. Special Shapes.—As in the case of the regular tile, special forms or shapes are required when using **T**-shaped tile for the jambs of windows, where box frames are used, as well as for sills, lintels, corners, starting blocks, etc.

29. Jamb Tile.—The form of tile used for jambs in connection with **T** tile is shown at *a* in Fig. 13 (*a*). The large dovetail grooves *b* in the wall side of this tile are for the reception of steel anchors *c* which fit into the grooves as shown in

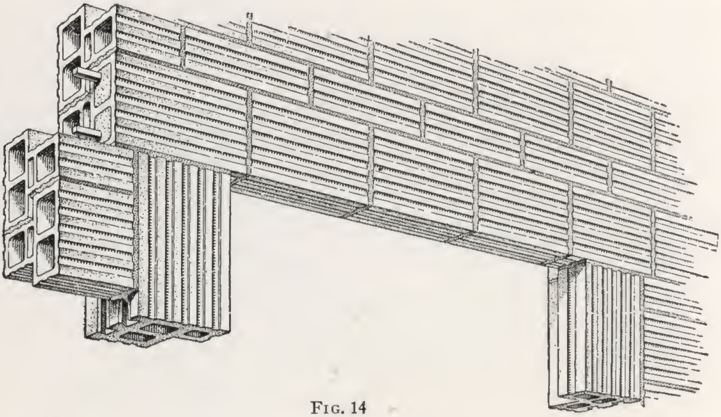


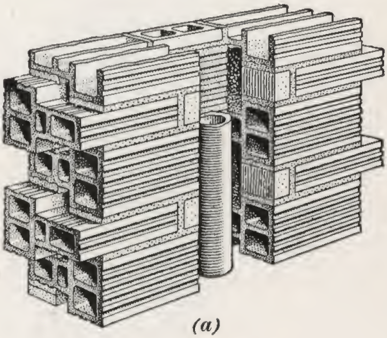
FIG. 14

the figure and tie the jamb blocks firmly to the wall. In (*b*) is shown a plan of one of these anchors. A plan of the jamb block is shown in (*c*).

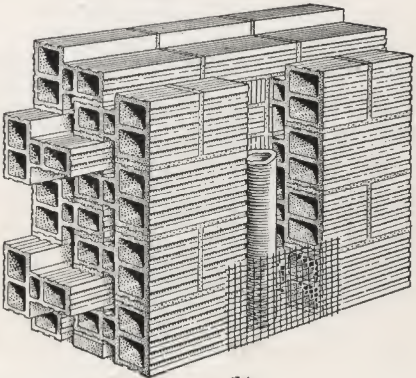
30. Lintels.—Lintels are formed by piling the required number of wall tiles on end and filling the cells with concrete, steel bars first being placed in the cells that are to be the upper and the lower cells when the lintel is in place. When the concrete has set, these lintels are set in place in the same manner as stone lintels. It is not safe to use a lintel of this type for an opening more than 5 feet in width. An illustration of a lintel formed of **T**-shaped tile is given in Fig. 14.

31. Chases.—In walls, vertical chases for the accommodation of soil and steam pipes, etc. are made in the form shown

in Fig. 15, by using the standard **T** tile as far as possible and filling in with pieces of tile obtained by cutting the standard tile or with bricks. In (*a*) is shown a chase in an 8-inch wall, and in (*b*) a chase in a 12-inch wall. These chases are covered with wire lath as shown in (*b*), and the plastering is continued across the chase opening.



(*a*)



(*b*)

Fig. 15

32. Corner Tile. In building a wall of standard **T** tile there will always be certain spaces left at the corners of the wall that will require special-shaped tiles to fill them out properly. In Fig. 13 (*a*) is an 8-inch wall which shows the spaces left to be filled with special corner tiles after the regular **T** blocks have been used as far as possible. The blocks *d* and *e* in (*a*) represent the corner blocks required for this purpose. The smaller block *e* is merely one-half of a block such as *d*. The blocks *d* are $6\frac{1}{2}$ inches high and are scored or marked so as to be broken easily into two $3\frac{1}{4}$-inch blocks when required. For 12-inch walls the same corner block as at *d* is used, as shown in Fig. 16 at *a* and *b*. These blocks are $6\frac{1}{2}$ inches in height and are used in both positions.

33. Starting Blocks.—It is necessary in starting a **T**-tile wall upon a level surface to use starting blocks as shown at *d*

and *e* in Fig. 12. The block *d* is a one-celled block while *e* is a solid piece of terra cotta or brick.

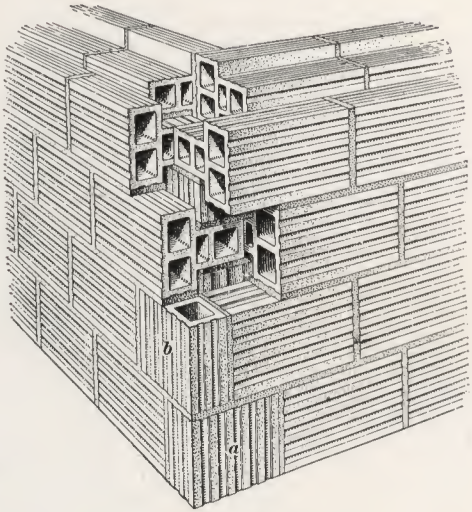


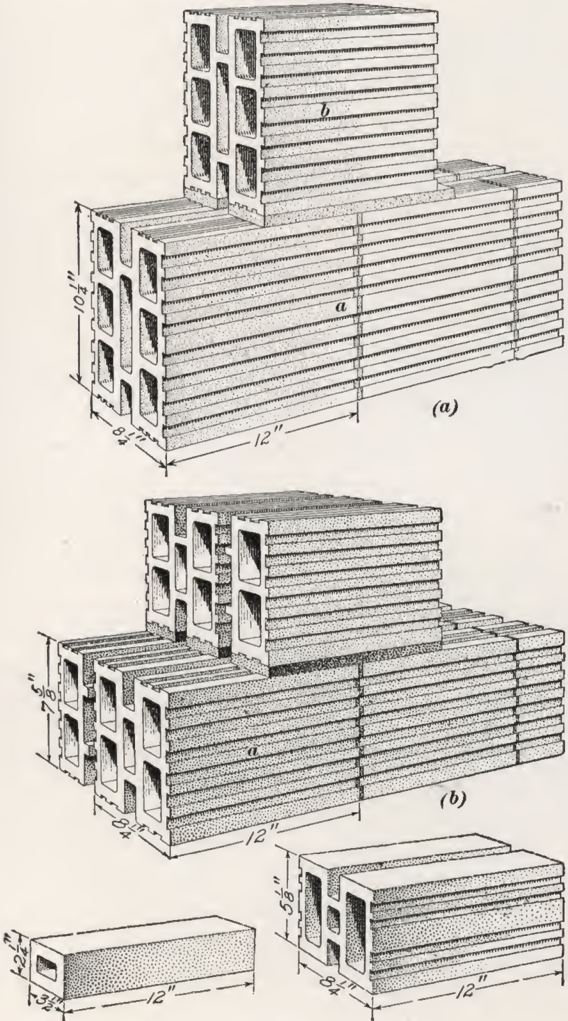
Fig. 16

34. Bonding Tile.—A special tile, shown at *f* in Fig. 12 (*c*), is required for walls 16 inches or more in thickness to complete the bond properly.

H-SHAPED TILE

35. Form and Use.—**H**-shaped tiles are also usually laid with the cells in a horizontal position, and the same advantages are claimed for them as for **T**-shaped tile. The **H**-shaped tile is illustrated in Fig. 17. At *a* in (*a*) is shown an $8\frac{1}{4}'' \times 10\frac{1}{4}'' \times 12''$ block. The height of this block, $10\frac{1}{4}$ inches, is the same as that of four bricks and three mortar joints; the block shown in (*b*) is $7\frac{5}{8}$ inches, or three bricks and two mortar joints, in height; that shown in (*d*) is $8\frac{1}{4}$ in. $\times$ $5\frac{1}{8}$ in. $\times$ 12 in., or two bricks and one mortar joint in height. The block shown in (*c*) is about the size of a common brick but 12 inches in length.

The slots in the tops and bottoms of these blocks serve to break the mortar joint so that it will not be continuous through the wall. This is shown in (*a*) and (*b*).



(*c*) Fig. 17 (*d*)

In (*a*) is shown the method of laying the blocks in an 8¼-inch wall and in (*b*) in a 13-inch wall.

H blocks have four heavy vertical webs which come above each other in the successive layers of blocks and thus form continuous webs from the foundation to the top of the wall. The surfaces of these blocks are finished with deep grooved scoring, scratched scoring, or smooth.

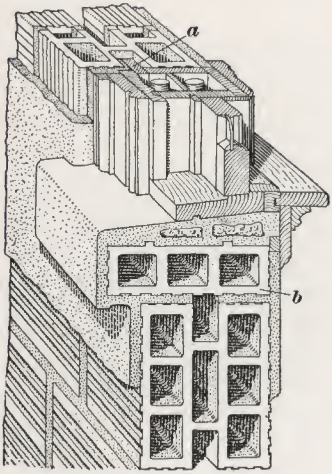


Fig. 18

36. Jamb Tile.—Jamb tiles may be formed by standing the regular **H** tiles with the cells vertical. A strip of wood is secured to the window frame and extends into the groove in the tile as shown at *a* in Fig. 18. This strip acts as a wind stop and also prevents the frame from falling out of the wall.

A special jamb block is made with full-size blocks as shown at *a*, Fig. 19, and half blocks *b*

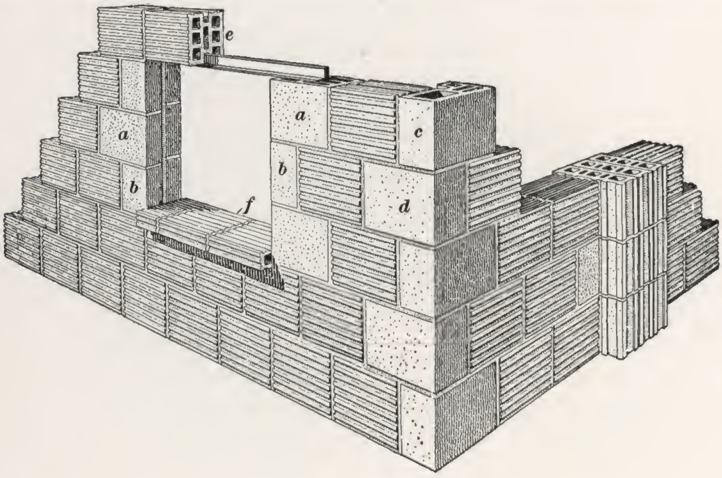


Fig. 19

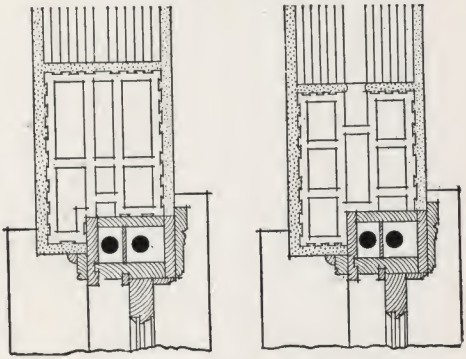
which are used alternately in the height of the jamb. This block is also shown in plan in Fig. 20 (*a*).

A third kind of jamb block is formed by cutting away a portion of the regular block so as to form a rabbet, as shown in (*b*), Fig. 20.

37. Sill Tile.—For sills a three-celled block made by cutting a standard **H** block in two, is used as shown in Fig. 18 at *b* and in Fig. 19 at *f*. Brick or stone may also be used as with the regular tile.

38. Corner Blocks.—A special corner block shown at *c*, Fig. 19, is used to complete the corners of walls laid up with **H** tile. The application of this corner block is shown at *e* and *d*.

39. Lintels. Lintels may be made with **H** tile in exactly the same manner as those in the regular block by piling up a sufficient number of blocks on end, inserting steel rods in the cells that will be at the bottom of the lintel when it is in place, and filling these with concrete. Lintels are also formed as shown in Fig. 19 at *e* by placing two steel angles back to back and setting standard tile on top of them.



(*a*) (*b*)

FIG. 20

SPECIAL TILE

40. Bakup Tile.—A special type of hollow tile, called *bakup* tile, is manufactured for use in backing up brick veneering. By its use a lighter wall can be built than would result if common brick were used for that purpose and one that is sufficiently strong to support the loads that are met with in moderate-sized buildings. Bakup tiles are made 5 inches, or two courses of brick, in height, and are either 4 in. × 12 in.

or 8 in. × 12 in. in horizontal dimensions, so as to form either a 9-inch or a 13-inch wall with the brick veneering. The use of this form of tile is discussed later on in this Section and is illustrated in Fig. 38.

41. Silo Blocks.—Special hollow-tile blocks manufactured for the purpose of building silos are illustrated in Fig. 21.

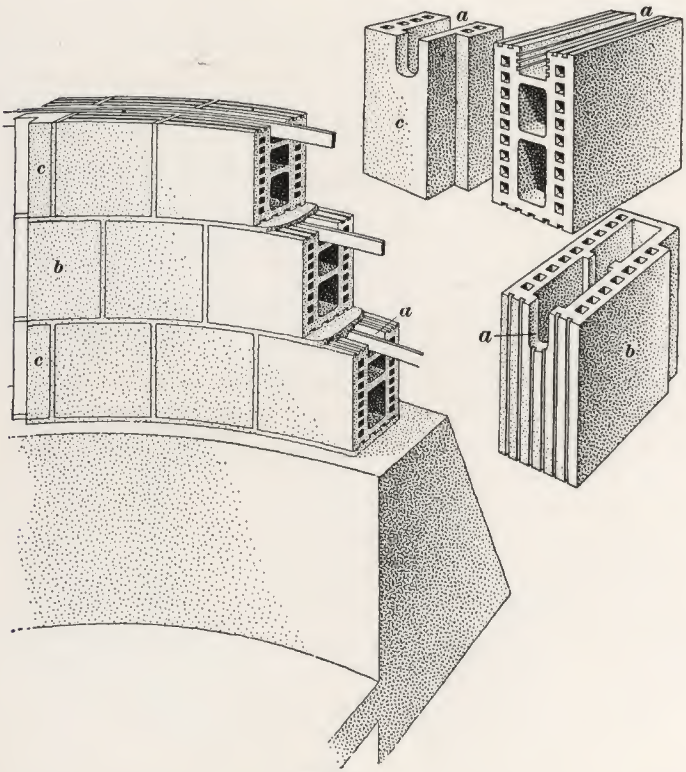


Fig. 21

The blocks are molded to a radius according to the diameter of the silo, and grooves *a* are formed in their upper edges into which iron or steel bands are set. The grooves are then filled with mortar. The purpose of the bands is to prevent the bursting of the silo which might be caused by the pressure of its

Courtesy of National Fire Proofing Co., Pittsburgh, Pa. FIG. 22

contents. Hollow-tile blocks with which certain standard sizes of silos can be built are kept in stock by manufacturers, and promptness in delivery of the material can be obtained by ordering silos of such sizes.

The blocks are made of vitrified clay, which is fireclay or shale that has been burned until it has become vitrified. They are therefore very durable and are not porous. The size of the regular silo block is 6 inches thick and 12 in. × 12 in. on the outer face. Where the doors to the silo occur, special jamb tiles *b* and the half jamb tiles *c* are used.

42. Textile.—*Textile* is a form of hollow tile that combines the features of the hollow-tile blocks with those of face brick. The Textile block is a hollow-tile block in which the exposed faces are finished like a rough face brick. A wall built of these blocks has the advantage of being hollow and of having the color and texture of rough face brick where exposed on the outside. The exterior effect of this wall is distinctive, as the faces of the Textile blocks showing in the face of the wall are about three times the size of a standard brick, or about 12 in. × 5 in. The wall has the appearance of having been built of very large bricks, which gives it a peculiar attractiveness. Fig. 22 shows a charming house, built of Natco Textile blocks, which illustrates the effect of this unit. In contrast with the Textile blocks, the string-course, lintels, sills, and the arch, are built of standard-sized brick, which emphasize the size of the Textile block.

Fig. 23 shows a few of the standard Textile blocks. They are used in practically the same manner as other hollow-tile blocks. In (*a*) is a regular block for use in the body of the wall. The face *a* is finished like the surface of a face brick. The back of the block *b* is grooved to afford a firm grip for plaster. These blocks are placed with the cells in a vertical position. In (*b*) is shown a lintel block made by placing two, three, or more special blocks together end to end, inserting rods *b*, and filling the middle cells *a* with concrete. When the concrete has set, a lintel is formed similar to those made for regular tile and is set in place in a similar manner.

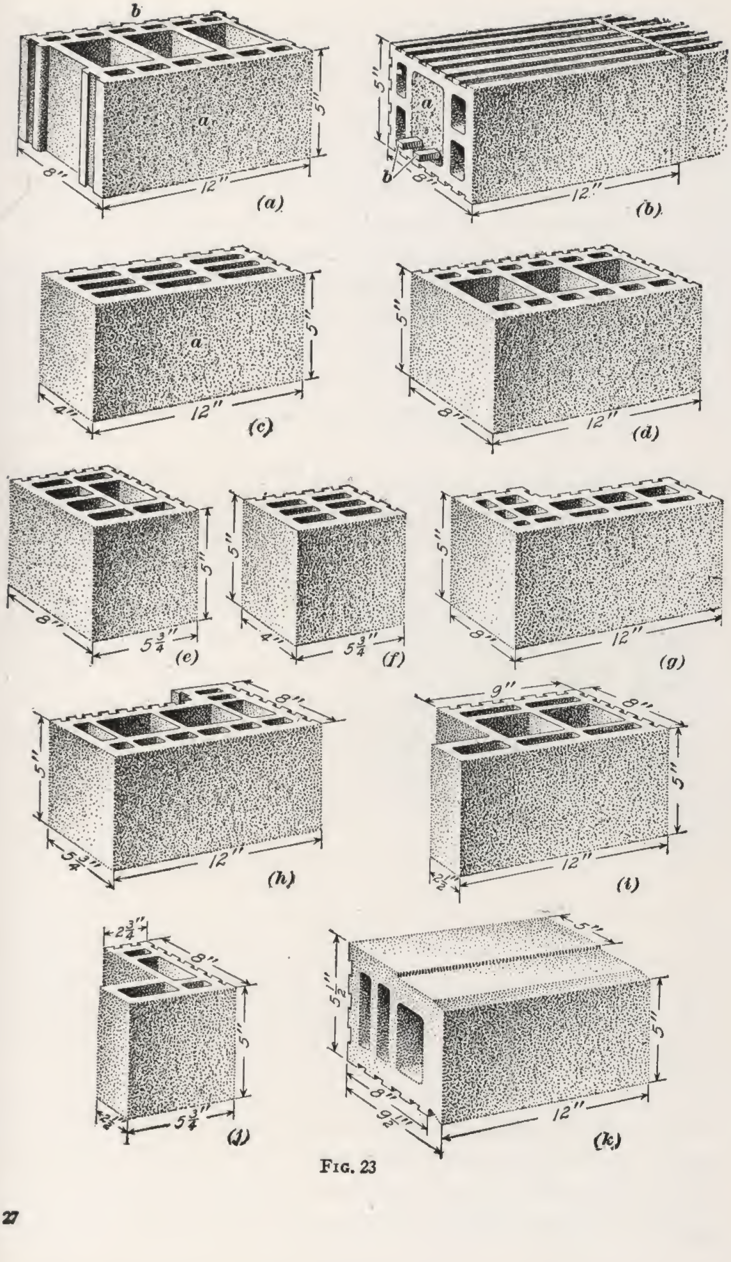

(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
(i)
(j)
(k)
a
b
5"
8"
12"
4"
$5\frac{3}{4}$"
9"
$2\frac{1}{2}$"
$2\frac{3}{4}$"
$5\frac{1}{2}$"
$9\frac{1}{2}$"

FIG. 23

In (*c*), (*d*), (*e*), and (*f*) are shown closures used in finishing jambs or sides of other openings in the tile wall that do not require to be rabbeted. Corner blocks are shown at (*g*) and (*h*), and jamb tiles at (*i*) and (*j*). A sill block is illustrated at (*k*). These various blocks are used in a similar manner to those already shown in the standard **T**-shaped and **H**-shaped tile. A study of the building shown in Fig. 22 will give a good idea of the method of using Textile blocks.

The shapes of these blocks are similar to those shown in Fig. 5, the difference being in the treatment of the outer face.

SURFACES OF TILE

43. Surface Treatment.—In addition to variations in shape or form, and in density, tile vary in the treatment given to their surfaces. These surfaces are formed according to the purpose for which the tile is to be used.

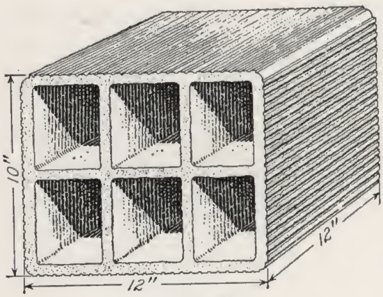


FIG. 24

The principal surfaces made on hollow tile blocks are *smooth, scratched, scored,* and *special* surfaces.

44. Smooth Surfaces. Smooth-surfaced tile is, as the term indicates, entirely smooth, and is used most often in building factories or warehouses where the tile is to be left in its natural state, uncovered by other materials such as stucco or face brick. Tiles are frequently made so as to present a smooth surface on one side only and are scratched or scored on the remaining surfaces. The smooth surface in this case is exposed.

45. Scratched Surface.—Scratched-surface tile is tile having its surface scratched as shown in Fig. 24 so that plaster and stucco will adhere to it more strongly. This surface is used also in walls that are to be faced with brick. Scratched-

surface tile is now so universally manufactured that it has become a standard type.

46. Scored Surface.—The scored surface is an exaggeration of the scratched surface and was designed primarily for walls that were to be plastered, the deep grooves providing an effective mechanical bond between the tile and the plaster. This style of surface is illustrated in Fig. 1. The scorings sometimes are plain rectangular depressions in the surface of the tile, and in other cases are dovetailed. The scored surface has also become a standard one, as it costs little or no more to manufacture than the scratched surface and forms an excellent bond not only for the stucco and plaster but for the mortar joints.

47. Special Surfaces.—Tiles are made with special finishes on the outside and inside for use where they are exposed on the finished surface of buildings and where ordinary smooth tile is not sufficiently attractive in appearance. These finishes are similar to those used on the surfaces of fine face bricks, and are used on the Textile blocks already described.

STRENGTH OF TILE

48. The strength of tile that is of interest to those using it in building is the compressive strength, or strength to resist crushing. This naturally varies with the hardness of the tile. The tile ordinarily used for wall blocks of any shape has a strength of about 5,000 pounds per square inch. This is the ultimate compressive or crushing strength. In practice only a fraction of this strength is estimated upon or employed, generally not more than one-sixth or one-eighth.

49. The building laws of Chicago require that the tile be "hard-burned terra-cotta tile of uniform quality, free from shrinkage cracks, with true beds, and having an ultimate compressive strength of not less than 4,000 pounds per square inch." The strength allowed in actual use is 500 pounds per square inch, or $\frac{1}{8}$ the ultimate compressive strength. These

figures refer to the actual terra-cotta material under compression, without regard to the cells.

50. The New York City building code estimates the compressive strength of tile blocks for the total area of the block, including shell, webs, and cell spaces.

Thus, a block 10 in. $\times$ 12 in. in horizontal section is considered as having a section of 120 square inches, and when tested must show an ultimate crushing strength of not less than 1,200 pounds per square inch when the cells are placed vertically and 300 pounds per square inch when the cells are placed horizontally. Hence the block just mentioned should show an ultimate strength of $120 \times 1{,}200 = 144{,}000$ pounds for the entire block, with cells vertical; or $120 \times 300 = 36{,}000$ pounds with cells horizontal.

The safe carrying capacity allowed by this code is 100 pounds per square inch with cells vertical, and 50 pounds per square inch with cells horizontal.

USES OF HOLLOW TERRA-COTTA TILE

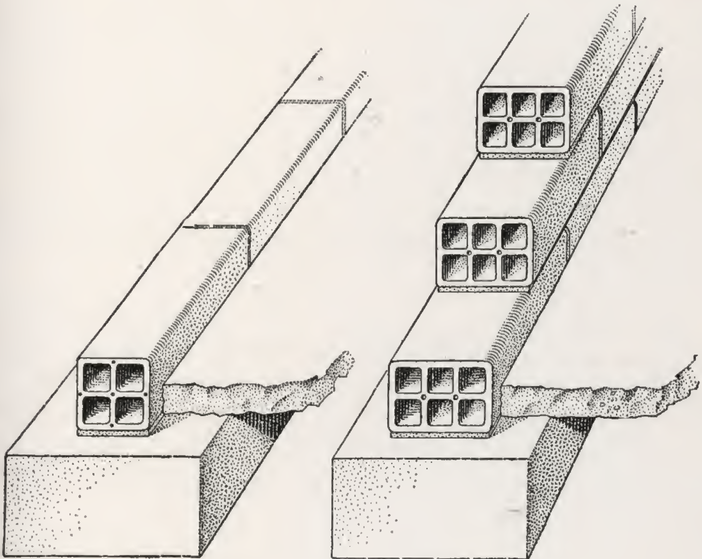
51. Various Uses of Hollow Tile.—Hollow tile in its various forms is used for erecting walls, partitions, piers, columns, floors, and roofs, especially when a fireproof construction is desired. The form of hollow tile here under consideration is that which is designed for building exterior walls to support floors and roofs. Tiles for this purpose are designed with strong vertical webs for supporting such loads, and may be used in conjunction with fireproof floors of terra cotta or used in connection with floors of wooden construction such as those in frame houses.

52. Choice of Tile.—As in the case of other building materials, architects and contractors have their preferences for certain kinds of tile or tile construction, and it is well to be familiar with all the best kinds of tile and their uses so as to be able to choose intelligently among them. Excellent buildings have been erected by using each of the different kinds of tile on the market and by following the methods recommended

by tile manufacturers. The selection depends upon the tile that can be delivered most promptly or which is the best or the cheapest.

FOUNDATIONS OF HOLLOW TILE

53. In many buildings hollow tile is used for the foundation walls. When used for this purpose the tile should be vitrified or glazed, as ordinary hollow tile such as is used for walls above ground will disintegrate in time if placed underground. In this respect it is like common brick, which is not



(a) *(b)*

Fig. 25

the best material to use below the surface of the ground unless very hard burned or vitrified.

54. Dense-Tile Foundations.—Dense tile is used for foundations, but when so used it is advisable to protect it from dampness by coating the exterior of the wall with some waterproofing compound such as asphaltum or coal-tar pitch. Another way of protecting this kind of tile is to give the outer

surface of the walls a good coat of Portland cement stucco or plaster as is done in the case of brick foundatons. The plaster should be composed of a mixture of 1 part Portland cement and 1 part sand, with not more than $\frac{1}{10}$ of a part of hydrated lime added.

55. Telephone-Conduit Tile for Foundations. When it is desired to use foundations of hollow tile, ordinary telephone-conduit tile will be found to be very satisfactory both as to endurance and economy. This kind of tile is used for underground conduits by the telephone companies. The tiles are 9 in. × 9 in. and 9 in. × 13 in. in cross dimensions, and 18 inches to 36 inches in length. They are illustrated in Fig. 25. The 9″×9″ tiles laid flat form a wall 9 inches in thickness as shown in (*a*), and the 9″×13″ tiles form a 13-inch wall, shown in (*b*). The larger units contain 6 cells and the smaller units 4 cells. This material will be found strong enough to sustain the ordinary loads of a dwelling house or other small building. Conduit tile is glazed, presenting the same texture as ordinary glazed sewer pipe, and will last for an indefinite length of time underground.

56. Telephone-conduit seconds are conduit tile with slight imperfections in finish, such as blisters or broken edges, and are often slightly warped. They are not satisfactory for the purposes of telephone conduits, but are perfectly useful for building foundation walls below grade. They are also much cheaper than perfect conduits, thus making them economical to use as foundation material.

57. Laying Conduit Foundations.—Telephone-conduit tile should be laid in full beds of cement mortar, and any corners that are broken should be patched with mortar. At the corners of the wall where the openings of the cells appear on the face of the wall, the ends of the cells should be closed up with brickbats and mortar.

58. Building-Code Restrictions.—The building laws of some cities make restrictions as to the use of terra-cotta hollow tile for foundations. Thus, the building code of New

York City specifies that hollow blocks may be used for foundation walls only when the upper walls are of frame or hollow building-block construction; also that the hollow spaces in the blocks shall be filled, as the construction progresses, with concrete consisting of not less than 1 part of cement to 9 parts of aggregate. Other cities require that buildings erected with hollow terra-cotta tile walls shall not be over four stories in height.

59. Other Foundations Used With Hollow Tile. In many sections of the country, cement concrete, concrete blocks, and stone are of no greater expense than hollow tile and are consequently used for foundations instead of hollow tile, even though the upper walls are to be built of tile.

In a house or small building, where the exterior walls above grade are to be 12 inches in thickness, a 12-inch foundation of concrete blocks or of solid concrete is usually sufficient.

Where the upper exterior walls are of 8-inch tile, a 12-inch foundation wall should be used. These thicknesses are for cellar walls that extend 6 or 8 feet into the ground.

EXTERIOR WALLS OF HOLLOW TILE

WALLS OF REGULAR, OR BOX-SHAPED, TILE

60. Wall Construction.—Illustrations of the individual tiles of box shape used in building walls have been shown in Figs. 1 (*c*), 2, 5, etc. Walls can be built of these blocks in various thicknesses, such as 6 inches, 8 inches, 10 inches, and 12 inches, by making the walls one block in thickness, as illustrated in Fig. 26 (*a*), (*b*), and (*c*). Thicker walls, which, however, are rarely called for, can be formed by combining these units in different ways so as to provide a sufficient bond, as shown in Fig. 26 (*d*). These blocks have a uniform height of 12 inches, but blocks of different sizes can be supplied by the manufacturers if necessary, as where the heights of the different stories of the building do not work out evenly by the use of

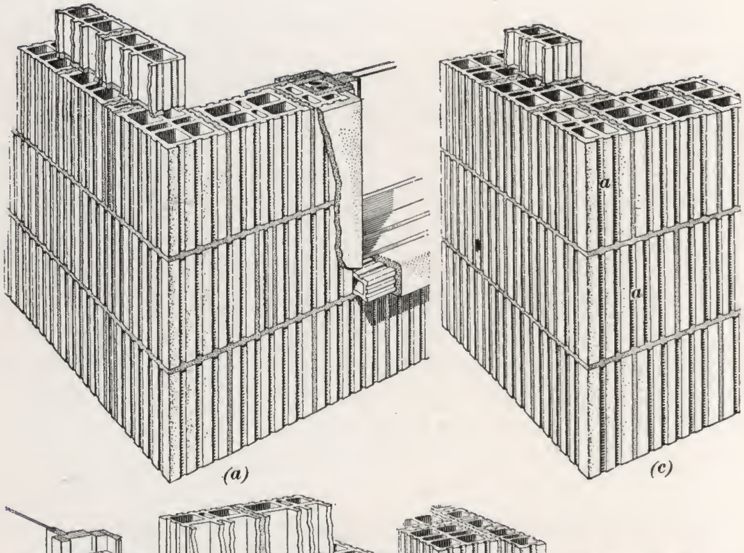


FIG. 26

blocks 12 inches high. It is an excellent plan when ordering hollow tile to send a set of plans to the manufacturer, who will then be able to ship exactly the right assortment of sizes of blocks.

As a wall is rarely required to have the same thickness for its whole height, the wall in the different stories can be made of different thicknesses. Thus, the cellar wall may be made 12 inches in thickness by using 12-inch blocks, and the first-story walls 8 inches thick by using 8-inch blocks. The second-story walls can be made 6 inches in thickness by using 6-inch blocks.

The New York building code requires that where the walls are reduced in thickness, the blocks on the top course of the

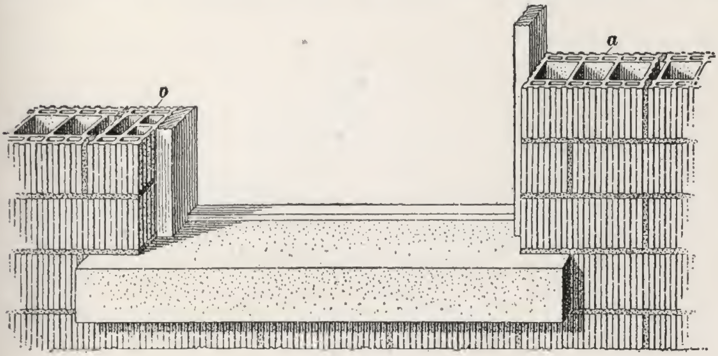


Fig. 27

thicker wall shall be filled solidly with concrete or covered with slabs of hard-burned terra cotta or concrete at least 1 inch in thickness.

61. Blocks of the kind shown in Fig. 5 are placed in a wall in the manner shown in Fig. 27, in which can be seen the construction around a door opening, a closure block being shown at *a* and a half closure block at *b*. A window opening is shown in Fig. 8 with a jamb tile at *a* and a half jamb tile at *b*; the construction of the sills is also shown. In Fig. 10 is shown a treatment for a lintel over a window opening.

62. Bedding in Mortar.—The bedding of tile, that is, the way in which tile blocks are set into the mortar, is a very

important feature of hollow-tile construction. Although different manufacturers claim that their particular forms of hollow tile offer advantages in bedding, bedding is really a matter of good workmanship. Any of the various patterns of tile that have already been described may be well laid if the workman understands the method and desires to do a good job. A good bed of mortar should always be placed beneath the

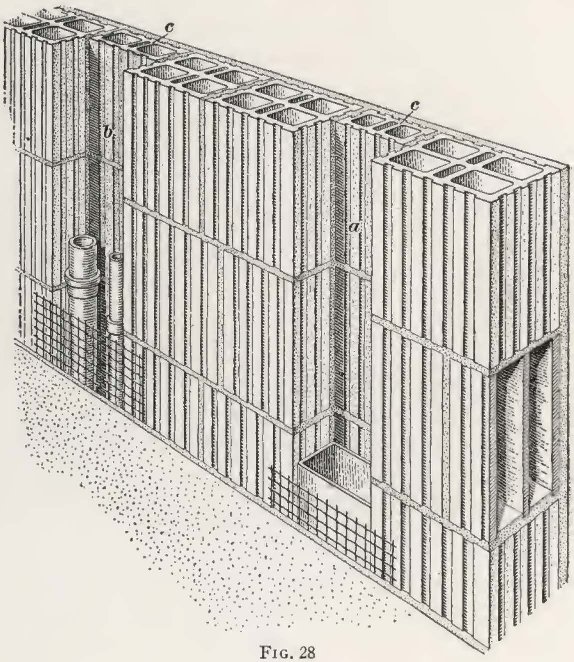
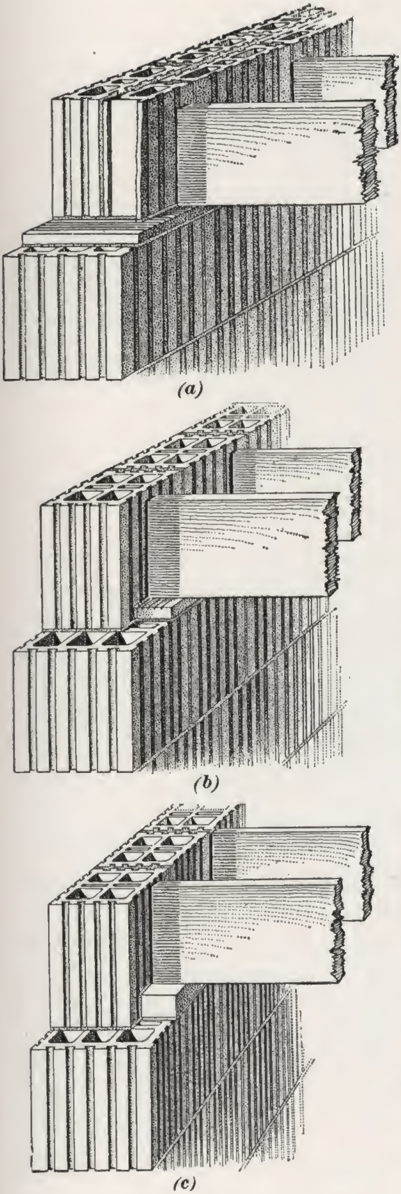


FIG. 28

bearing surfaces and in the vertical joints at both faces, but it is also desirable that the mortar joints should not be continuous through the thickness of the wall.

63. Mortar.—The best mortar to use in bedding hollow tile is a mortar made of 1 part Portland cement and 3 parts of clean sand to which $\frac{1}{10}$ part hydrated lime may be added. The mortar should be made stiff enough to adhere readily to the thin edges of the tile.



(a)

(b)

(c)

Fig. 29

64. Cutting Tile. Terra-cotta tile can easily be broken with a mason's trowel or a hammer in the same manner as brick is broken. It can, therefore, be cut to fit special positions where there are no stock tiles of the proper size and shape on hand.

65. Chases. — It is generally necessary to accommodate pipes, such as plumbing, heating, and gas pipes, as well as electric-wire conduits, within the thickness of the wall. Chases, or vertical recesses, must therefore be formed either by building recesses in the wall or cutting them in the wall after it is built. One of the advantages claimed for the regular tile is that chases can be cut wherever necessary after the wall is completed. It is not advisable, however, to allow the plumber, the gas-fitter, the heating contractor, and the electrician to hammer out chases in the wall wherever they may choose, hence it is better to build chases into the wall at properly designed points so as to accommodate all

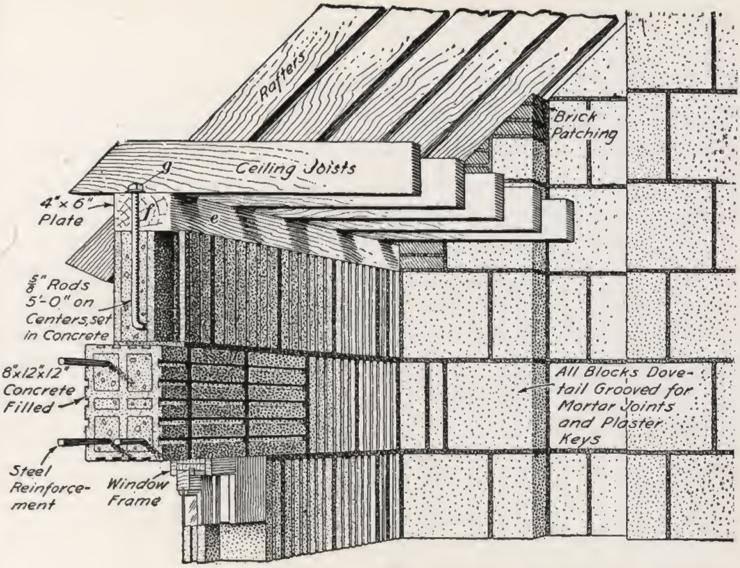
the necessary pipes. Fig. 28 illustrates the method of building chases so that it will not be necessary to ruin the wall with a hammer. The wall at *a* and *b* is made thinner by using thinner blocks *c*, these blocks extending the full width of the chases. Over the chases, strips of wire lath are secured which close the chases entirely and afford a base to receive the plastering. Chase *a* accommodates a heating flue, and chase *b* a soil and a waste pipe.

66. Corner Blocks.—With the regular tile the problem of finishing the corners of a wall is easily solved by the use of regular stock blocks such as shown at *a* in Fig. 26 (*b*), (*c*), and (*d*), and the manufacturers generally send a sufficient quantity of these corner blocks to complete the wall. It is a great advantage to send a set of plans to the manufacturer when ordering, as he will then supply all the special pieces that may be needed to complete the job.

67. Supports for Wooden Floorbeams on Regular Tile.—Where wooden floorbeams are used, they naturally rest on the wall at each end, and the wall should be built so as to provide a suitable bearing for them. As a rule, the wall diminishes in thickness at the level of the floorbeams so that a shelf is formed by the projection of the lower wall beyond the upper wall, and upon this the floorbeams generally rest, as shown in Fig. 29. Where the difference in the thickness of these walls is 4 inches, a sufficient bearing is afforded for the average wooden joist, and flat tiles as in (*a*) and (*b*) or a row of bricks as in (*c*) is laid on top of the 4-inch projection. Upon these tiles or bricks the ends of the joists are placed.

Where there is a difference of only 2 inches in the thickness of the walls or where the walls of both stories are carried up at the same thickness, it becomes necessary to extend the ends of the joists into the upper-story walls so as to obtain at least a 4-inch bearing. This condition calls for a special arrangement of the tiles at the level of the joists, as illustrated in Fig. 30.

In this figure the joists are shown bearing upon a 1-inch flat slab *a* that is carried entirely through the wall. This affords a


Rafters
Brick Patching
Ceiling Joists
g
4"x 6" Plate
f
e
5/8" Rods 5'-0" on Centers, set in Concrete
8"x12"x12" Concrete Filled
All Blocks Dove-tail Grooved for Mortar Joints and Plaster Keys
Steel Reinforce-ment
Window Frame

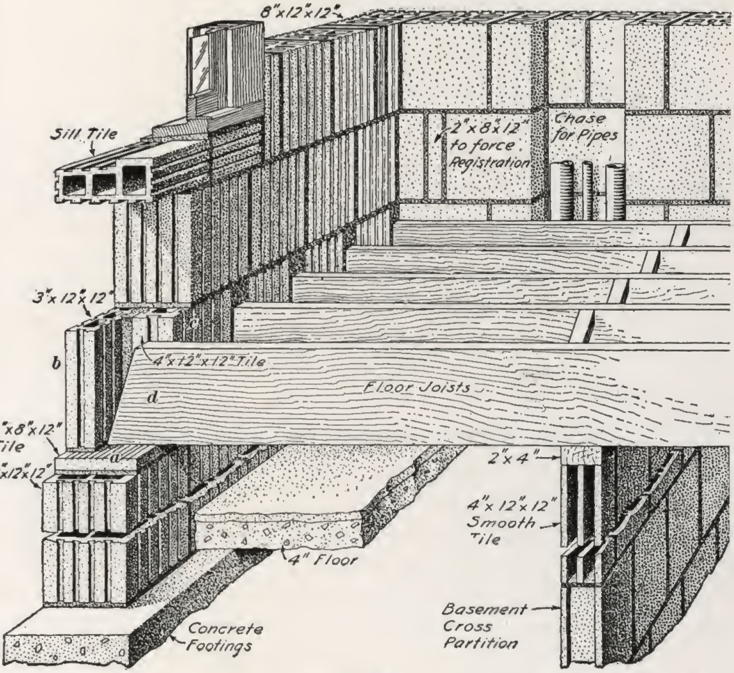

8"x12"x12"
Sill Tile
2"x 8"x 12" to force Registration
Chase for Pipes
3"x 12"x 12"
c
b
4"x 12"x 12" Tile
Floor Joists
d
1"x 8"x 12" Tile
a
8"x12"x12"
2"x 4"
4"x 12"x 12" Smooth Tile
4" Floor
Basement Cross Partition
Concrete Footings

Fig. 30

flat bearing for the ends of the joists. Between the ends of the joists and the outside of the wall a row of thinner wall tiles *b* is placed and a second row of tiles *c* is placed between the beams. These two rows together form a base upon which the wall above rests.

68. A method that is sometimes used for supporting wooden floor joists is shown in Fig. 31 in which the joists are suspended by means of steel joist hangers *a,* which are in turn supported upon flat 1-inch slabs *b.* An advantage in this method is that the trouble of fitting the tile around the ends of the joists is avoided.

69. Anchoring Wooden Floor Joists.—The ends of joists when projecting into a tile wall should be cut with a *fire cut,* as shown at *d,* Fig. 30. This cut is so called because it permits the beam to fall out without injuring the wall if the timber should be burned off.

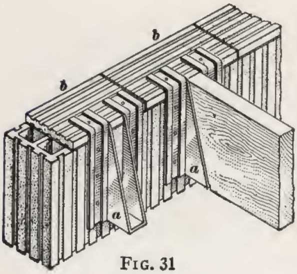


FIG. 31

Every fourth joist should be anchored to the wall by means of a wrought-iron rod, strap, or *dog,* driven into the top of the joists and built into the masonry. The purpose of these anchors is to tie the floors to the walls, and thus give greater stability to the building. Walls parallel to floor joists should be anchored by metal straps nailed to three or four joists and turned up into the wall.

70. Supporting Fireproof Floors on Regular Tile. The several forms of fireproof flooring used in connection with hollow-tile construction will be described and illustrated later, but the provision that must be made in the walls to receive the floors will be described at this point.

The floor systems mostly used in connection with hollow-tile construction are the flat concrete slab, the combination floor of hollow tile and reinforced concrete, the Johnson system, and the New York wire-truss system; and they all require that the

bearing walls supporting them have a flat tile placed over the ends of the cells to receive the floors. These floors extend to within 4 inches of the outside of the tile wall and a 3-inch facing tile is placed as shown at *a* in Fig. 32. At *b* is shown the flat bearing tile on which rests the floor system *c*, the weight of which is thus transferred to the bearing wall *d*. The upper-story wall *e* is started directly on the floor construction, as shown in the figure. In Fig. 33 the floor construction is shown resting on the lintel over an opening.

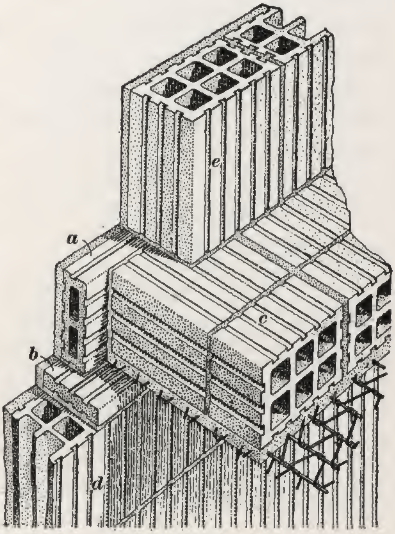


FIG. 32

71. Concentrated Supports.—In the floor systems that have been mentioned the load is distributed over the bearing walls quite uniformly and does not necessarily bring any concentrated load on any particular point in the wall. Where steel girders are used, concentrated loads occur at the bearings of these girders, and the wall must be especially strengthened at these points. This is done by filling the cells of the tile with concrete for two or three courses below the bearing of the beam, or even down to the footings, to form a solid masonry pier under the load. Where the cells of the tile are in a horizontal position, a brick pier is sometimes built extending down for several tile courses and spreading out toward its lower part. This distributes the load over a large area of wall below.

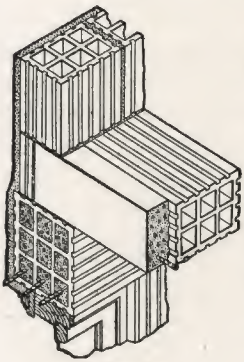


FIG. 33

72. Supporting Non-Fireproof Roofs on Regular Tile.—Flat non-fireproof roofs are supported in the same manner as non-fireproof floors; that is, the rafters, being flat, are supported in the same manner as floor joists. Where the roof pitches, the lower ends of the rafters are supported, as shown in Fig. 30, on a plate *e* which is anchored to the wall so that it will not be pushed off by the thrust of the rafters,

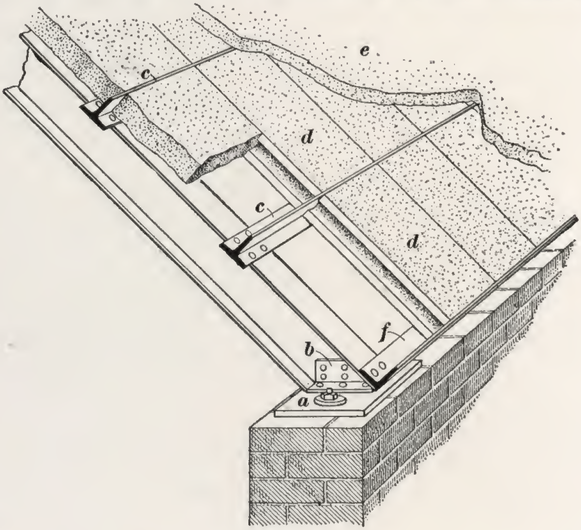


FIG. 34

although as an additional safeguard the lower ends of the rafters are generally tied together by means of the attic-floor construction. The anchors *f* consist of bolts which extend down into the wall, either through the blocks or between them, and also extend above the plate so that nuts and washers *g* can be used to hold the plate in position.

73. Supporting Fireproof Roofs on Regular Tile. As a matter of fact, it is unusual to build fireproof roofs on dwellings. Generally the houses are built fireproof up to and including the attic floor, a timber construction is used for the roof, and this is covered with a fireproof covering or roofing, such as slate, tile, or asbestos shingles, so that the roof itself will not catch fire from without.

As in the case of the non-fireproof construction, flat roofs of fireproof construction are similar to the floors in their design.

For pitched roofs of fireproof construction the same principles are used as in non-fireproof construction. As shown in Fig. 34, a metal plate *a* is anchored to the wall by bolts built into the wall and extending up through the plate so that a nut may be screwed on the top of the bolt to hold the plate in position. The rafters, which are generally **I** beams, are anchored to the plate as shown at *b*, and **T** irons *c* and an angle iron *f* are secured to the rafters at such a distance apart as to take the

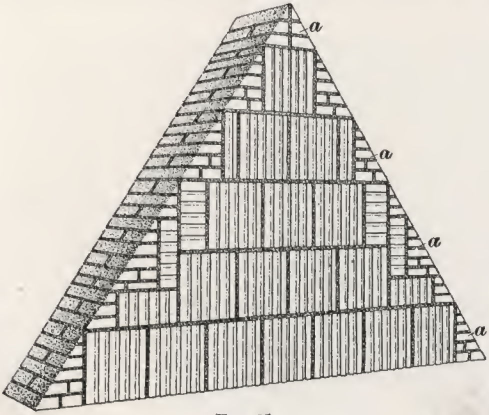


FIG. 35

tile *d* called book tile. A layer of cinder concrete *e* is then placed over the book tile and the roofing is nailed to it.

74. Pitched roofs may be made of the combination construction used for floors, which is described later on. This construction is exactly the same as a floor set on a slope. It is an expensive construction and is used only on elaborate work.

75. Finishing Gables.—In building gable walls of hollow tile it will be found wasteful to cut the blocks to a triangular shape to fill in the spaces *a*, Fig. 35. These triangles are therefore generally filled with brickwork as shown in the figure.

WALLS OF H TILE

76. The shapes of **H** tile have already been shown. The sizes are 12 in. × $8\frac{1}{4}$ in. horizontally, and $5\frac{1}{8}$ in., $7\frac{5}{8}$ in., and $10\frac{1}{4}$ in. vertically. The vertical heights, plus the thickness of one mortar joint, correspond to two, three, and four courses of common brick with the necessary mortar joints. A single block makes a wall $8\frac{1}{4}$ inches thick. When a 13-inch wall is required, the thickness is made of one $8\frac{1}{4}$-inch tile and a half tile. These half tiles are made and carried in stock but may also be obtained by simply splitting the whole tile. The half tiles in such a wall are placed on the outside and the inside of the wall in alternate

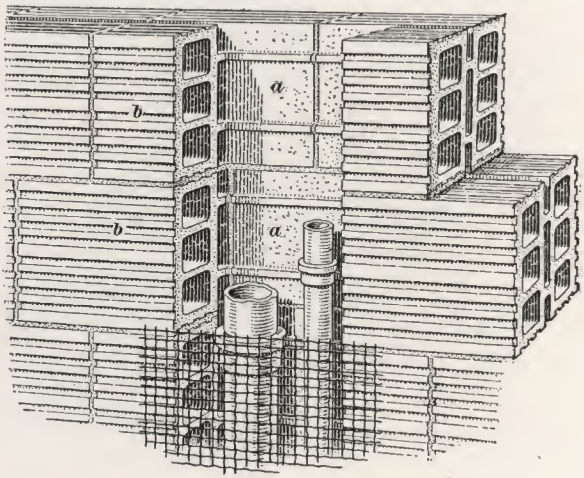


FIG. 36

courses as shown in (*b*) in Fig. 17. It will be noticed in this figure that the horizontal bed of mortar is broken into 3 parts so that it is not continuous through the wall.

77. Supporting Floors on H Tile.—Floor joists of wood are supported directly upon the upper surface of the blocks. The joists extend into the wall so as to bear upon two lines of vertical webs. The spaces between the ends of the joists are filled with $4\frac{1}{8}$-inch tiles, which are the standard blocks split in two. Fireproof floors are supported in the

same manner, but such floors must be carried to within about 4 inches of the outer face of the wall so as to have as large a bearing as possible.

78. Supporting Plates.—The plates for supporting the lower ends of roof rafters on **H**-tile walls are secured in the same manner as on brick walls or walls of regular tile. Bolts are built into the wall so as to extend down about 16 or 18 inches and also to project through the top of the plate and receive a nut.

79. Finishing Gable Walls.—The triangular spaces in gable walls are finished in the same manner as for regular tile, as shown in Fig. 35 at *a*.

80. Chases.—Chases may be formed by the use of blocks of half thickness, as at *a*, Fig. 36, and bonding them into the full-thickness blocks *b*.

WALLS OF T-SHAPED TILE

81. **T**-shaped tiles are laid up in the wall as shown in Figs. 12, 13, 14, 15, and 16. In the 16-inch wall in Fig. 12 (*c*), a special tile *f* is required to complete the bond properly. Walls of other customary thicknesses, however, can be built with the regular **T**-shaped tile. A solid block of special shape is required to start the wall at the bottom, as shown at *e*, Fig. 12 (*a*), (*b*), and (*c*).

Jamb blocks are placed on end at each side of the opening, and must be securely anchored to the wall as shown in Fig. 13. Corner blocks of two different heights, as shown in Fig. 13 at *d* and *e*, are required to finish the corners properly. Chases are built as shown in Fig. 15.

Floors and roof plates are supported in the same general way as is done in **H**-tile walls.

VENEERED WALLS

82. By veneering the outer surface of a hollow-tile wall with brick, the advantages in appearance due to the brick facing, and of the air spaces and lightness due to the hollow-tile construction, are both secured.

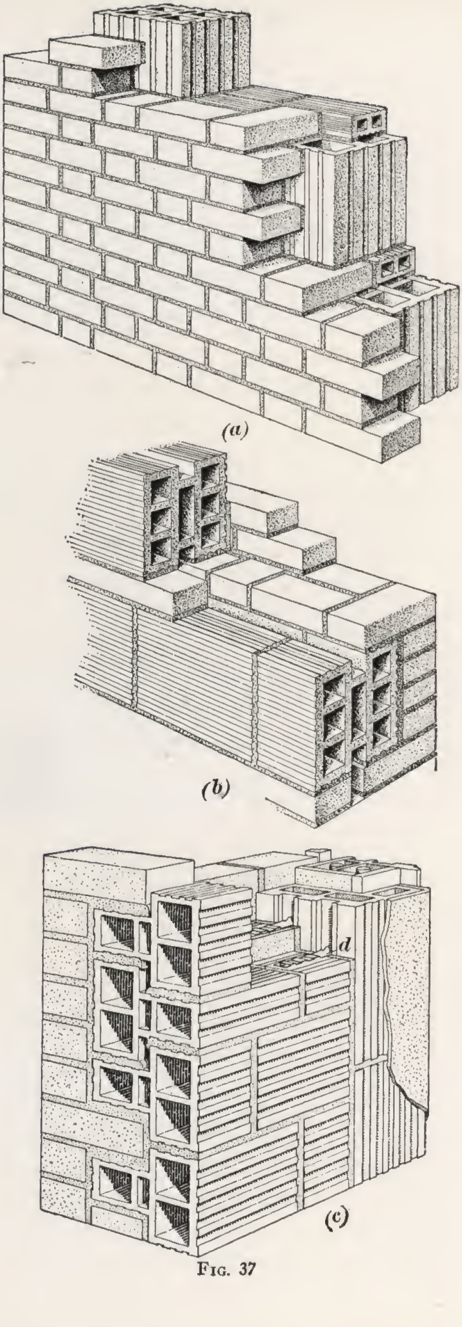


Fig. 37

The principal problem in constructing a brick-veneered wall is the bonding of the brick face securely to the tile backing. The various types of tile mentioned are designed so that this bonding may be readily accomplished. In Fig. 37 are shown the methods of tying or bonding the brickwork to the tile work

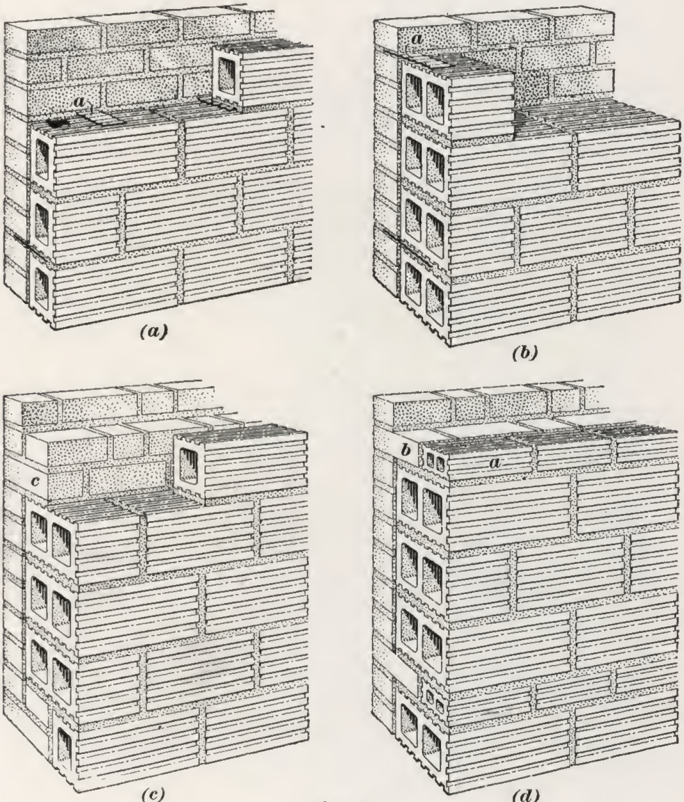


Fig. 38

of the three types already described. In (*a*) is shown the method used with the regular tile; in (*b*) and (*c*), with **H** tile and **T** tile. When it is desired to show no headers in the brick facing it is necessary to tie it to the tile with metal ties, in the manner shown at *a* in Fig. 38 (*a*) and (*b*). When brick-veneered walls are used, it is a frequent custom to use solid

stone sills and lintels for the window openings as well as stone string-courses, as is done in a brick building with solid walls.

83. Bakup Tile.—A special type of hollow tile, called *bakup* tile, is manufactured for use in backing up brick veneering. By using this tile a very light and economical wall can be built. The *bakup* tiles are made with one face smooth for use in places where it is not desired to plaster the interior face of the wall. These tile are sometimes called *"Jumbo"* brick.

Where the brickwork shows only stretchers on the face, the bond to the backing is made by using metal wall ties as shown

Fig. 39

at *a* in (*a*) and (*b*), Fig. 38. Where, however, heading courses of brick are used, headers can extend into the wall as shown in (*c*) and (*d*). By using hollow-tile brick, as shown at *a* in (*d*), only one course of face brick is needed in forming the bond instead of two courses as shown in (*c*).

Fig. 39 illustrates a method of laying up a wall consisting of a brick-veneered face, backup-tile backing, and metal ties.

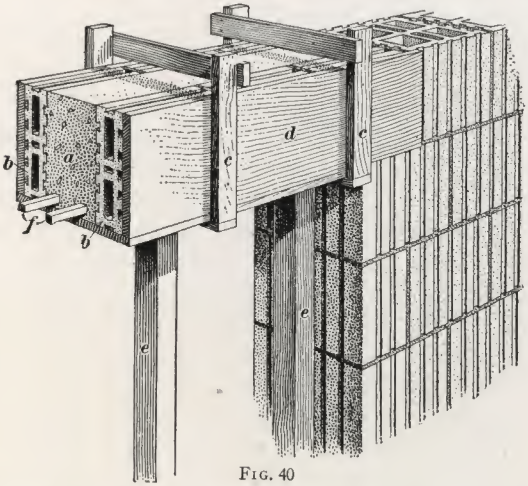


Fig. 40

Two of these ties are shown projecting from the back of the face-brick veneering between the hands of the two men.

OPENINGS IN WALLS

84. Openings.—Openings in walls are generally for doors and windows. The blocks that are used around such openings, such as lintels, jambs, and sills, have been illustrated.

The lintels are the only blocks that vary with the width of the opening. Lintels have been shown for spans of not over 5 feet. For lintels of a greater span than 5 feet, reinforced concrete or steel must be depended upon.

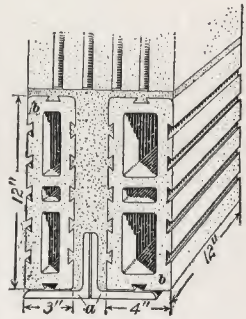


Fig. 41

In Fig. 40 is shown a lintel which consists of a reinforced-concrete beam *a* faced with hollow tile *b*. The concrete beam is designed to carry all the load coming from the wall above the opening as well as from floor-beams that may rest on this wall.

The lintel is faced with thin blocks of hollow tile, which afford a better surface for stucco and plaster than the concrete surface would. These tiles adhere strongly to the concrete lintel, as the concrete flows into the dovetail grooves when the lintel is cast.

A lintel of this type is generally cast in position. The lintel shown in this figure is made in a wooden form, as shown at *d*. This form must be strongly supported by the struts *e*, and its sides must be braced as shown at *c*, so that they will not spread apart when the concrete is cast in place. The tiles *b* are first placed in position and the rods *f* are set so that they will be about 1 inch above the bottom of the lintel. The concrete is then poured into the space *a* and allowed to set for a few days until it has attained considerable strength, when the forms may be removed.

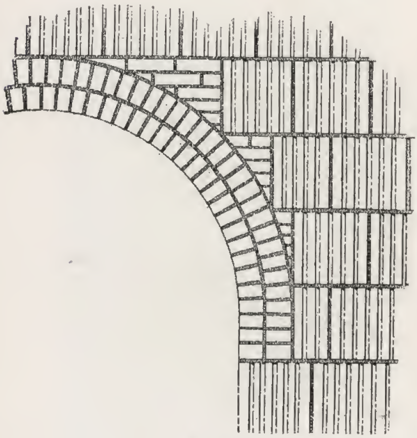


FIG. 42

A lintel that requires no forms and that will be ready to bear the load within a day or so is shown in Fig. 41. This lintel is virtually a steel lintel formed of two angles *a*, upon which terra-cotta blocks *b* are set, and concrete or cement mortar is filled in between them. The strength of this lintel is that of the two steel angles.

85. Arched Openings.—Arched openings in hollow-tile walls are made by using either plain bricks in the form of row-lock arches as shown in Fig. 42, or by using hollow-tile blocks as voussoirs, or arch blocks, as shown in Figs. 43 and 44.

In the arch shown in Fig. 42 the rectangular tile blocks are not cut to fit the triangular spaces, as brickwork is used to fill up these spaces, as shown.

COLUMNS AND PIERS

86. Columns.—Many designs for hollow-tile houses require round columns in such places as the front entrance or

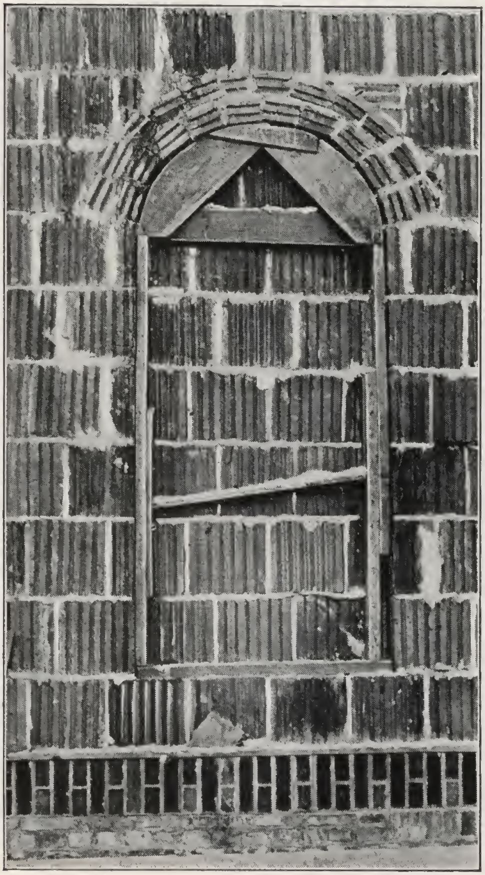


FIG. 43

on porches. Manufacturers make a *radius tile,* or tile molded with a curved surface, such as shown at *a* in Fig. 45, which can be laid up to form cylindrical columns of different diam-

eters. When these columns are expected to support an extra-heavy weight the interior of the cylinder is filled in solidly with concrete *b*, which is sometimes reinforced with rods or bars *c*.

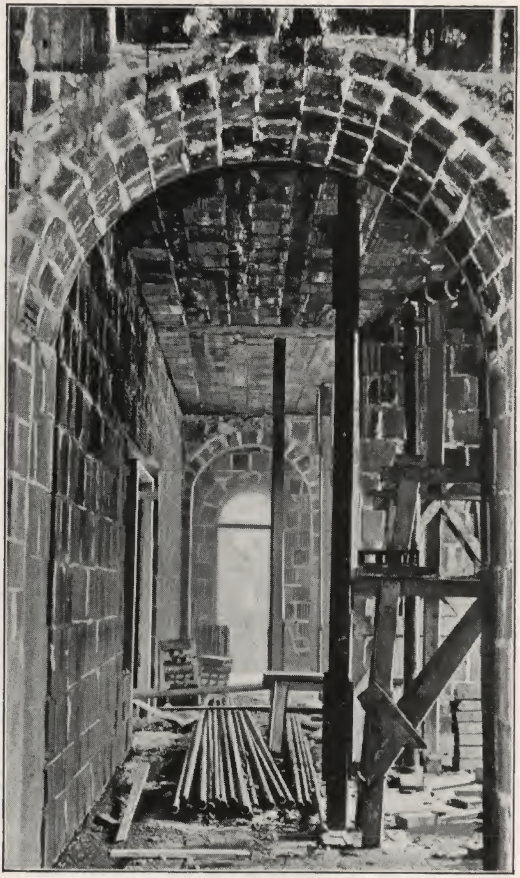


Fig. 44

Columns of this description are practically reinforced-concrete columns and will support loads in proportion to the diameters of the concrete cores. The enclosing tile is generally scored on the outside so as to hold a finishing coat of stucco.

87. Piers.—Piers, as shown in Fig. 46, can be built of stock-size blocks, which must be set up so as to break joints in

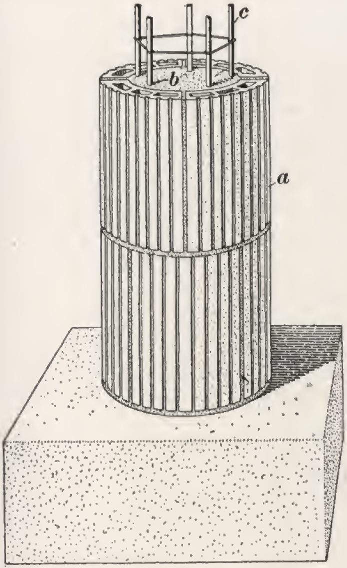


Fig. 45

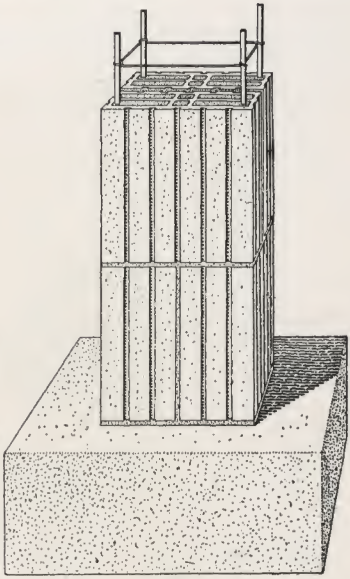


Fig. 46

alternate courses. These piers should be filled with concrete when supporting heavy loads. Reinforcing rods may be added as shown where greater strength is required.

ATTACHING FURRING, TRIM, ETC. TO WALLS

88. Use of Wooden Laths.—Many architects prefer to fur the interiors of all external walls of hollow-tile construction, as this provides space between the tiles and the plaster for gas and water pipes and electric conduits. It also affords a means of preventing cold striking through the walls to the plaster and causing moisture to condense on the face of the plaster. When the use of furring is contemplated, wooden laths are often built into the horizontal joints between the tiles at proper distances apart to afford nailing for the furring strips. This is illustrated in Fig. 47 at *a*.

89. Metal Wall Plugs.—Another good method of providing nailing for wooden furring is to use metal wall plugs, shown at *b* in Fig. 47. These plugs are small bent corrugated plates of metal that are set in the mortar joints while the wall is being built, and receive and hold nails driven into them through the furring strips as shown in the illustration.

90. Self-Clinching Nails.—Self-clinching nails may also be used for fastening wood to tile. These nails, shown in Fig. 47 at *c*, are driven through the furring strips and also

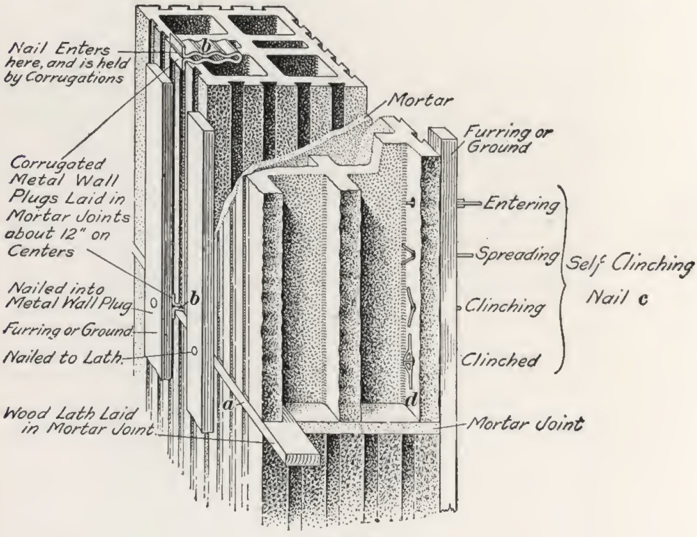


FIG. 47

through the shell of the tile, in which holes have previously been punched. The last blows of the hammer cause the nails to spread and clinch on the back of the shell as shown at *d*. An enlarged view of a self-clinching nail is shown in Fig. 48. In (*a*) the nail is shown closed and ready to drive, in (*b*) the nail is shown driven through the furring and tile and clinched.

91. Toggle-bolts are shown in Fig. 49. These bolts have heads *a* that are hinged to the bolts. A hole is made in the tile of sufficient size to allow the head to enter as shown

in (b). When the head has passed through the hole the head is turned on the hinge so that it stands at right angles to the hole. The threaded shank of the bolt extends through a hole bored through the furring and is fitted with a nut which is screwed up and holds the furring firmly in place. In (c) is a view of a toggle-bolt in position.

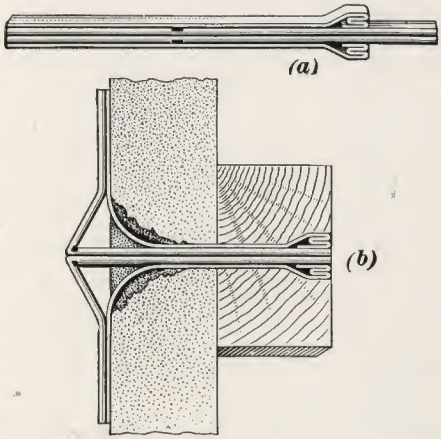


FIG. 48

92. Ankyra Ankor Bolts.—A useful form of expansion bolt for use in securing furring, grounds, etc., to hollow-tile walls is known as the Ankyra Ankor bolt and is illustrated in Fig. 50. In (a) is shown the bolt, which consists

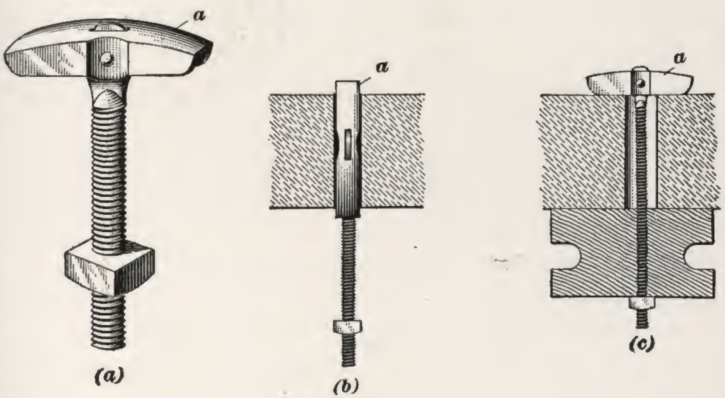


FIG. 49

of a divided shell a, a collar b with a projecting portion or lug c, and a collar d which is threaded to receive an ordinary wood screw such as e e. In (b) the bolt is shown drawn up so that the shell a expands in three directions. In (c) the bolt is

shown under various conditions. At *a* is a hole that is punched through the terra-cotta tile *b* into which the shell of the bolt *c* has been driven. A slight tap of the hammer will drive the lug *d* into the tile and the lug will keep the shell of the bolt from revolving or slipping into the hole. The shell is then pulled together as shown at *e* and *f* by means of a device inserted into it. This establishes the shell firmly in place and it is ready to receive the screw that is to hold the furring in place as shown at *h* and *i*. The tighter the screw is turned the firmer the hold this bolt will take. The position that a bolt will take in a corner is shown at *j* and the method of holding in solid terra cotta is illustrated at *k*.

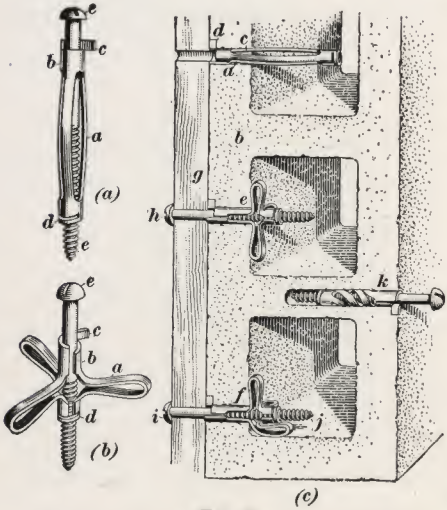


FIG. 50

93. Grounds to which trim, base, wainscoting, picture moldings, etc. can be nailed can be secured to the tile walls in the same way as furring strips.

PARTITIONS OF HOLLOW TILE

94. Partitions.—Interior partitions of hollow tile are usually made thinner than outside walls, because they do not have to resist the weather and frequently they carry only light loads. Interior partitions in ordinary houses are built of 3-inch, 4-inch, or 6-inch blocks. In a fireproof house, where the weight of fireproof floors must be taken into account, the main bearing partitions are sometimes made of 8-inch blocks.

It is necessary that tile partitions be rigidly supported. They must therefore rest upon solid walls or partitions beneath or upon steel beams. When fireproof floors are used, partitions in the upper stories may be set on these floors slightly to one side of the partitions below, or, in other words, need not be set directly above them.

The blocks used for partitions are those used in fireproofing and are described in the Section entitled *Fireproofing of Buildings.*

FLOOR SYSTEMS

95. The floor systems used in connection with hollow-tile walls are not peculiar to them. In fact any of the flooring systems used in other buildings can be used equally well in buildings having hollow-tile walls. As these floor systems are described elsewhere, it would be repetition to describe them extensively here, consequently a merely superficial description will be given.

96. Non-fireproof floors, such as are used in ordinary frame structures, are most frequently used in tile buildings, but are not to be recommended, on account of their inflammable nature.

97. Hollow-Tile Fireproof Floors.—While any type of fireproof floor can be used in connection with hollow-tile walls, the most natural fireproof floor to use is one that is composed of the same material as the wall; that is, hollow terra-cotta tile.

Two systems that make use of plain hollow-tile blocks as an essential part of their structure are the *combination floor system* and the *Johnson system.* These types of floors are the ones most used in dwellings. In larger buildings the flat-arch floor systems, the segmental-arch system, and the wire-truss system are employed. As these last-mentioned systems are described in the Section entitled *Fireproofing of Buildings,* they will not be described here.

98. The Combination Floor.—What is generally known as the *combination floor* is frequently employed for

ordinary spans. This floor consists of what may be described as reinforced-concrete beams with hollow tile held between them.

In building such a floor, planks are first erected as a form or temporary support for the entire floor. Upon this form or platform, sometimes called *centering,* the tiles are laid in rows about 16 inches on centers with the cells lying in the direction of the rows. After the tiles are all laid, reinforcing rods are placed at the bottoms of the spaces between the rows and

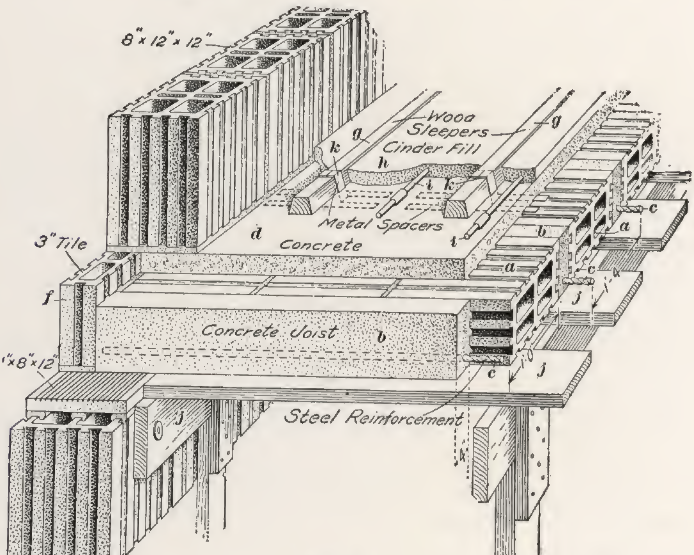


Fig. 51

concrete is poured into the spaces and over the top of the entire construction to a thickness of about 2 inches, as shown in Fig. 51. This figure shows the hollow tile of the floor at *a,* the reinforced beams at *b,* the reinforcing rods at *c,* and the 2-inch layer of concrete over the top of the tile at *d.* The rods *c* are kept up above the centering about $\frac{3}{4}$ inch, so as to be entirely embedded in concrete and thus protected from rusting and fire. The entire construction rests upon 1-inch flat tile slabs set on the wall, and is faced on the outside of the wall

with 3-inch facing tile *f*. The upper wall rests directly upon this floor construction.

On top of the floor construction, wooden cleats, or sleepers, *g* are laid about 12 inches on centers to afford nailing for the wooden floors. These sleepers are made from $2'' \times 4''$ stuff and are beveled on both sides. They are secured in place by the use of sheet-metal spacers *k*, that are held down by the weight of the concrete that is placed upon them, and are nailed to the sleepers. It is customary to fill in between these sleepers with cinder concrete *h*. After this fill has become thoroughly

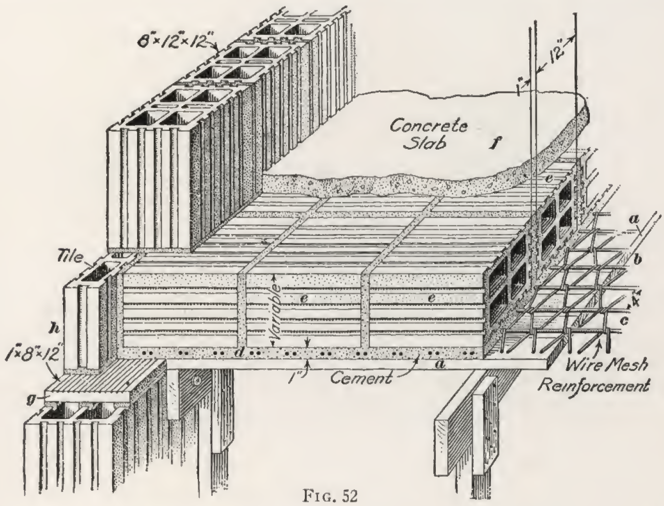


FIG. 52

set, a layer of heavy building paper is placed on top and the finished floor is nailed to the sleepers. Before the cinder concrete is placed between the sleepers, gas and water pipes and electric-wire conduits, as at *i*, are put in place.

The floor is supported on the wooden forms *j* until it has thoroughly set, when the forms may be removed.

99. The Johnson Floor.—Another type of fireproof floor that is frequently used in dwellings and other small buildings is known as the Johnson system, and is formed largely of hollow-tile blocks. The Johnson-system floor is sometimes more economical for wide spans than the combination floor.

In erecting the Johnson floor, a centering *a*, Fig. 52, consisting of a floor made of matched boarding is built, and on this platform a network of steel reinforcement *b* is laid, usually consisting of a heavy metal fabric reinforced by steel reinforcing bars *c*, placed at intervals of 5 or 6 inches. This metal is then embedded in a layer of cement mortar about 1 inch thick. On top of this layer, tile blocks *e* are laid in rows as in combination floors, but about 1 inch apart. The size of the tile varies according to the span and the load.

Concrete is poured into the spaces between the rows of blocks and, where the loads are ordinary, filling these spaces is sufficient. When the loads are heavy a concrete slab *f*,

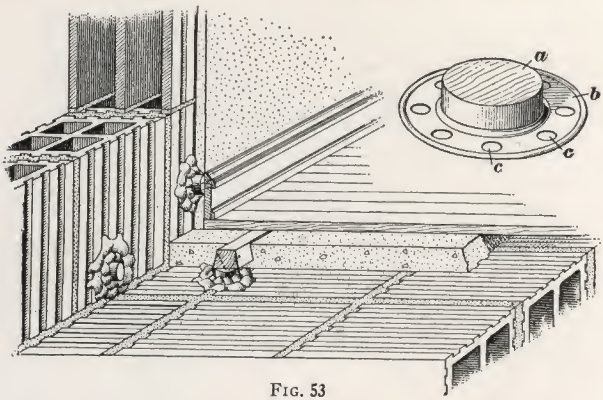


Fig. 53

about 2 inches in thickness, is poured over the tops of the blocks at the same time. As in the case of the combination floor, this floor rests on a flat slab *g* on the wall and is faced on the outside of the wall with a 3-inch facing tile *h*. The details of placing sleepers, pipes, and the finished floors are the same as in the combination floor.

100. Securing Sleepers, or Cleats, to the Floor Construction.—To secure wooden floor sleepers, or cleats, to which the floor is nailed, there are several appliances. One of these consists of small galvanized-iron hooks each of which has a flat end that is embedded in the cinder concrete and a sharp end that is driven into the cleat when the cleat is in its

proper position. These hooks are spaced about 12 inches on centers and hold the cleats firmly in position. Other methods consist of metal strips that are embedded in the cinder concrete and have projecting ends that can be bent over the cleats and nailed to them as shown at *k* in Fig. 51.

A very efficient and ingenious method of attaching furring, sleepers, and grounds to hollow tile is by the use of what are known as *spot grounds,* illustrated in Fig. 53. These grounds consist of a disk of wood *a,* firmly attached to a circular flange of sheet metal *b,* which is perforated with holes *c.* The grounds are secured to the terra-cotta surface by the use of plaster of Paris or Portland cement. Before the plaster has set, the grounds are brought to the correct level so that the furring or sleepers when nailed to the grounds will be straight and level. When the plaster or cement has hardened they afford firm spots into which nails may be driven.

ROOF CONSTRUCTION

101. As has been stated, fireproof roofs are not generally placed on hollow-tile buildings. When, however, they are used they are similar in construction to floors or fireproof roof constructions that are described elsewhere.

STUCCO FINISH

102. Need of Finish on Tile.—The natural appearance of a tile wall is not very attractive or artistic unless the tile is made with special surfaces, as in the case of Textile blocks. Tile walls are, therefore, generally covered with a stucco, or plaster, which is applied so as to produce artistic effects.

COMPOSITION OF STUCCO

103. Stucco.—What is known as *stucco* is in reality a cement plaster formed of Portland cement, sand, lime, and water, and applied in the same manner as ordinary wall plaster.

104. Ingredients of Stucco.—The Portland cement may be of any of the standard brands such as the Atlas, Alpha, Lehigh, Universal, or Vulcanite. These cements are generally of a gray or mouse color and may be used in the first coats of stucco and in the finishing coat when this gray tint is satisfactory.

Portland cement is also made of a pure white color. Such cement is used when it is desired to produce a pure white color in the finishing coat; also when light tints of various colors are required. The white cement merely lightens the tint of any coloring material that may be added to the stucco without destroying the quality of the color. When delicate tints or tones of pink, yellow, or brown are sought, white Portland cement should be used.

105. The **sand** should be clean, free from loam, salt, and other impurities. It should consist of coarse and fine particles mixed together rather than of uniform-sized grains. Ordinary sand possesses a yellowish or reddish color which affects the color of the stucco. When used with a gray Portland cement it results in a gray or mouse-colored stucco. The colors of

the gray cement and the sand greatly modify the effect of mortar colors that are used in coloring stucco and make it impossible to obtain light tints such as buffs, pinks, yellows, etc.

In order to obtain delicate light colors in the stucco, white cement should be used and also *white sand.* Instead of white sand, pulverized marble is sometimes used. This is called *marble dust.* By the use of white cement and white sand or marble dust, light pure tints can be obtained by using small quantities of mortar colors.

With the use of white cement and sand as a base, delicate and desirable tints can be produced by adding **crushed stone** of various colors to the stucco. The stones used for this purpose are marbles, granites, and other crystalline rocks, as well as pebbles that possess high colors. These colored particles of stone should show in the face of the stucco in order to produce a color effect in the wall.

106. The best form of **lime** to use is hydrated lime, which is a carefully and scientifically slaked lime and is in the form of a fine white powder. It can be mixed dry with cement and sand, and when all these ingredients are thoroughly mixed the water can be added.

Lump lime is sometimes used instead of hydrated lime, but must be carefully slaked, strained, and allowed to stand for a week or ten days before using.

107. The **water** used in mixing the stucco should be free from alkalies, acids, and vegetable matter, as these materials may interfere with the setting of the cement.

108. Mortar Colors.—The coloring materials used in tinting stucco are known as *mortar colors,* and are the same as are generally used in coloring mortar used in brick and stone masonry. The best of these mortar colors are sold in pulp form so that they will mix readily with the mortar or stucco. When mixing different batches of colored mortar for the same job, great care should be taken that the same fixed amount of colors is used for a given amount of mortar or stucco. If this is not done the different batches of mortar will show different

tints on the surface of the wall. Only the best and most permanent colors should be used or else the colors will fade or disappear in time.

APPLICATION OF STUCCO

109. The First, or Scratch, Coat.—When the hollow-tile walls of the building have been finished and the roof is in place, the building is ready to be *stuccoed*. As with any plastering, the weather conditions should be suitable; that is, neither too hot nor too cold.

Scaffolds should be erected entirely around the building, after which the mechanics can put on the first coat of stucco,

FIG. 54

which should be pushed firmly against the tile so that it will flow into the grooves and make a secure bond. Deep-grooved tile is best for use in work that is to be stuccoed, as the grooves provide a good mechanical bond between the stucco and the tile. When glazed tile is used, the dovetail scorings on the tile are the only means of holding the plaster to the tile, as the

glazed surface affords no bond whatever. In semiporous tile the slight absorptive power of the surface of the tile affords a grip for the stucco.

When the first coat has hardened slightly it should be *scratched*. This is usually done with a piece of board that has its edge notched, as shown in Fig. 54. This scratching gives a rough surface to which the second coat will adhere. The first coat should thoroughly fill all the grooves in the face of the tile and cover the tile with a thickness of about $\frac{1}{4}$ inch.

110. The Second Coat.—The second coat is applied when the first coat has set but before it has dried. It is when putting on this coat that the surface of the plastering is made true and smooth. This is done by using long straightedges at the corners of the building and around the openings and working the stucco to an even surface between them, all hollow spaces being filled in and projecting ones cut down. All this straightening is done while putting on this second coat.

111. The Third Coat.—After the second coat has set, but before it has dried, the third, or *finishing,* coat is put on. This third coat is the one that is visible to the eye and gives character to the appearance of the building. This character or effect is caused by the color and the texture of the finished surface. By the use of various materials and processes a large variety both of color and texture can be obtained.

FINISHES

112. Color.—As has just been stated, the appearance of the stucco depends upon the manner in which it is finished with regard to color and texture. The matter of obtaining various colors has been considered under the head of the Composition of Stucco. When mortar stains are used, the mass of the stucco is colored uniformly. When, however, the color depends upon the color of the sand or broken stone which is mixed with the stucco, it is generally found necessary to clean away a film of cement which naturally covers these colored aggregates,

so that they may show in the surface of the wall. This is done by scrubbing the wall with brushes and clean water when the stucco is fresh, or by using dilute muriatic acid and brushes if the stucco is several days old. This treatment removes the film of cement and exposes the aggregates in their natural color and brilliancy and the color effect of the wall is determined by the color of these aggregates.

113. Texture.—The texture, or degree of roughness, of the surface of the stucco, has a great effect upon its appearance. A perfectly smooth and even surface can be obtained by using fine materials and working them to a perfectly uniform and smooth surface. It is found, however, that such a treatment is likely to prove flat and uninteresting in its effect. A rough surface is generally more interesting, due to the play of light and shade upon it caused by the projecting particles of mortar.

This texture is obtained by using coarse sand, grit, and pebbles in mixing the stucco, as well as by the method of applying the stucco. The wall surface may be finished smooth by using a steel trowel or it may be made rough by using a cork or wooden float or by placing a piece of carpet over the float. The surface may be roughened by stippling it before it has hardened and a rough but uniform effect obtained. The stucco is often thrown against the second coat and a rough surface produced. The stucco may be mixed with grit or small pebbles and thrown against the second coat and a very rough surface obtained.

Thus it will be seen that there are numerous devices used to obtain what are considered as desirable effects in the finishing coat.

114. Sand Finish.—A *sand-finished* or *sand-floated* surface is obtained by using coarse sand in the final coat. This coat is put on in the usual manner. When it has hardened slightly it is rubbed with a wooden float, using a circular motion which brings the sand to the surface of the stucco and gives a pleasing roughness or texture to the wall.

115. Rough Cast.—When the finishing coat is brought to an even surface, a mixture of cement and sand is thrown against the face of the wall by means of a small wooden paddle or a whisk broom so as to roughen it more or less uniformly.

116. Pebble Dash.—The finishing coat is brought to an even surface and pebbles varying in size from $\frac{1}{4}$ inch to $\frac{1}{2}$ inch are thrown against the soft stucco surface so as to be distributed as evenly as possible. The pebbles should be wet and should be thrown against the surface with sufficient force to make them adhere, or they may be pressed into the stucco with a clean board.

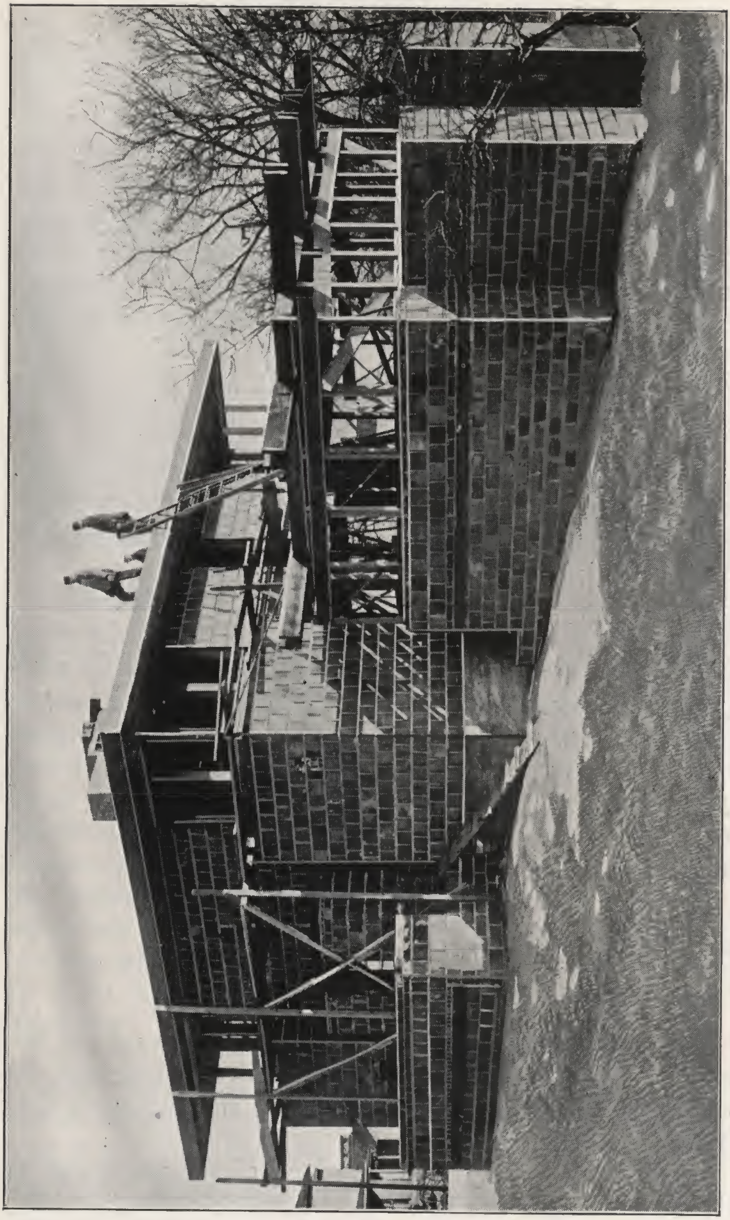
117. Water Necessary.—The stucco should be kept moist at all times until it has been completed. It should be frequently sprayed or should be covered with wet burlap so that it will not dry out too soon.

EXAMPLES OF BUILDINGS OF HOLLOW TILE

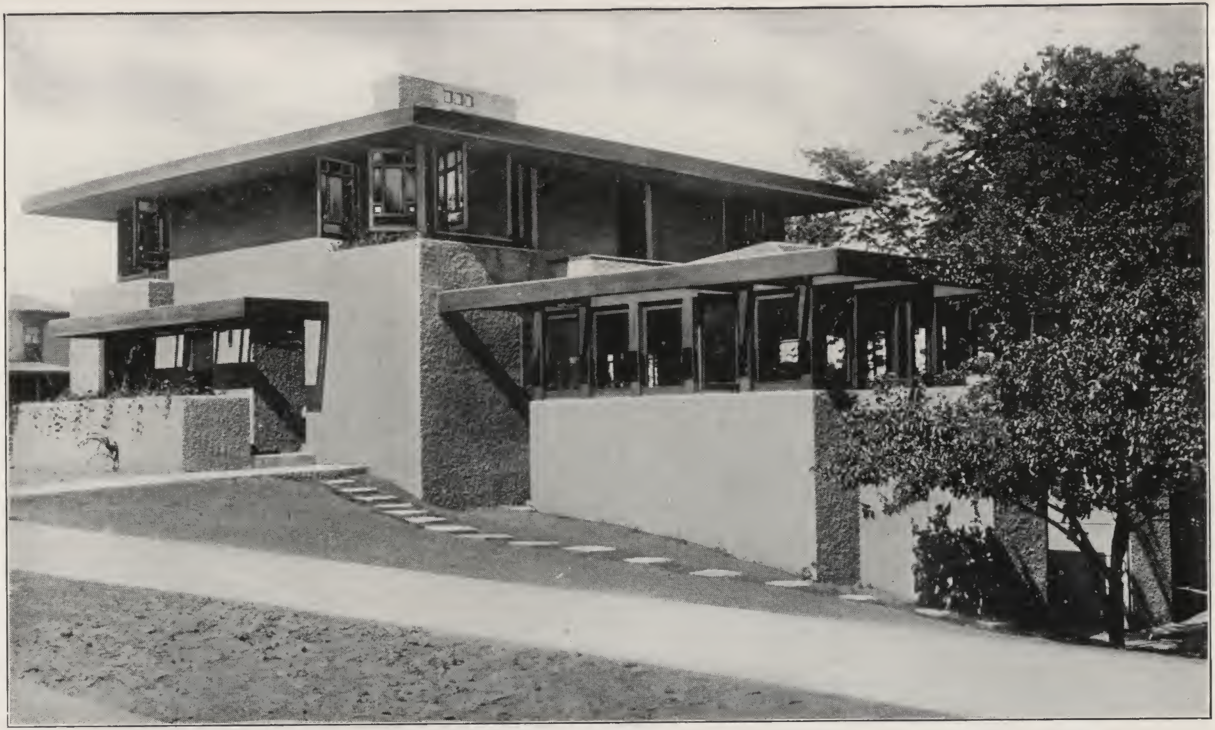
118. Dwellings.—Hollow tile is used for dwellings of all kinds, such as bungalows, cottages, and mansions. Illustrations of a dwelling built of Denison load-bearing, or **H**-tile, blocks are given in Figs. 55 and 56. Fig. 55 shows the building ready for plastering and Fig. 56 shows the plaster or stucco coat in place. The stucco surface has been finished in rough cast and presents a coarse and vigorous texture. Figs. 57 and 58 are two dwellings built of **H** tile and ready to receive the stucco coating. These illustrations show quite clearly the methods used in building with hollow-tile blocks.

119. Apartment Houses.—Apartment houses are frequently built with walls of hollow tile, such tile being used for outside and inside walls up to the roof; and sometimes fireproof floors are used.

Examples of apartment houses built of tile are shown in Figs. 59 to 64, inclusive. Fig. 59 shows an apartment building built of interlocking tile, or **T**-shaped tile. This illustration



Courtesy of the Denison Fire-Proofing Co., Mason City, Iowa Fig. 55



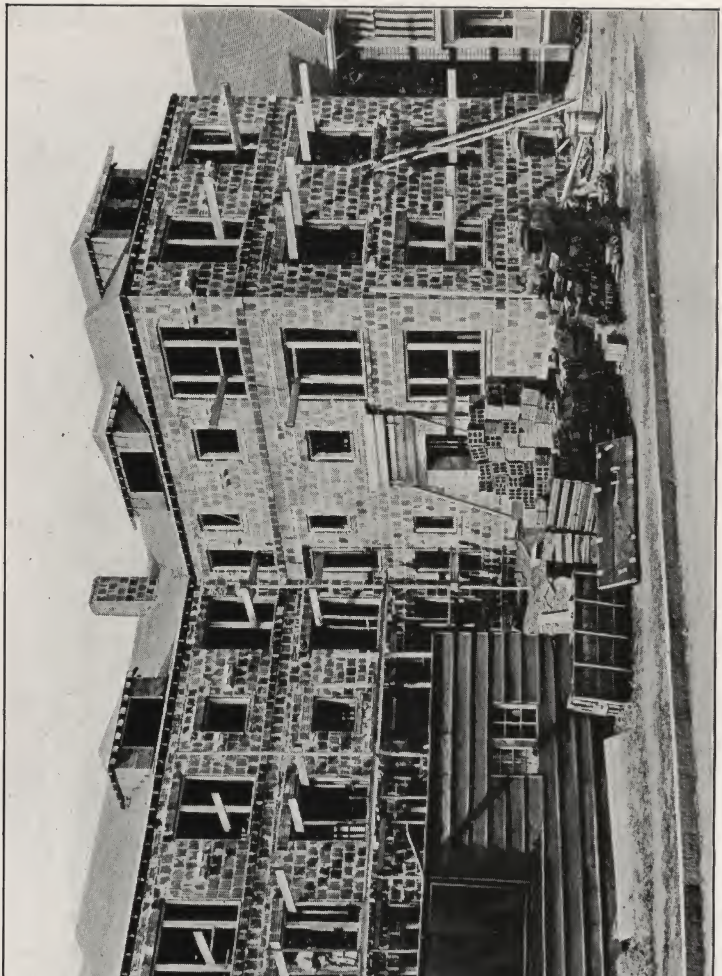
Courtesy of the Denison Fire-Proofing Co., Mason City, Iowa FIG. 56

Courtesy of the Denison Fire-Proofing Co., Mason City, Iowa Fig. 57

Courtesy of the Denison Fire-Proofing Co., Mason City, Iowa FIG. 58

Courtesy of the Denison Interlocking Tile Corporation, Cleveland, Ohio FIG. 59

Courtesy of the Denison Interlocking Tile Corporation, Cleveland, Ohio Fig. 60



Courtesy of National Fire Proofing Co., Pittsburgh, Pa. FIG. 61

shows the characteristics of hollow-tile construction. The lintels and sills are made of tiles. In some cases corner blocks and jamb blocks have not been used. The cell openings show at the window jambs and corners but will be closed up with cement mortar and will present a satisfactory surface to receive the stucco. Segmental arches are shown on the front porch and are formed of face brick, as shown in the finished building, Fig. 60.

120. Fig. 61 shows an interesting example of hollow-tile construction built of Natco hollow tile. The sills and lintels are of tile as is also the sill course under the third-story windows. The chimney is also built of tile. Corbels of stone to receive the cornice brackets and the balconies are also shown in place. Fig. 62 shows this building finished with stucco rough cast, making a very attractive and interesting structure.

121. A very large apartment house is shown in Figs. 63 and 64. Fig. 63 shows the exterior walls built of Natco, or standard-shaped, tile. In this case the doorways, string-courses, and the trim of some of the windows are of stone and are built into the terra-cotta wall. The wall is shown with its stucco coating in Fig. 64. It will be noticed that the stucco in the first story has been treated to represent stone having rusticated joints. Quoins have been formed of stucco in the upper stories at the corners. The effect of this building is dignified and substantial.

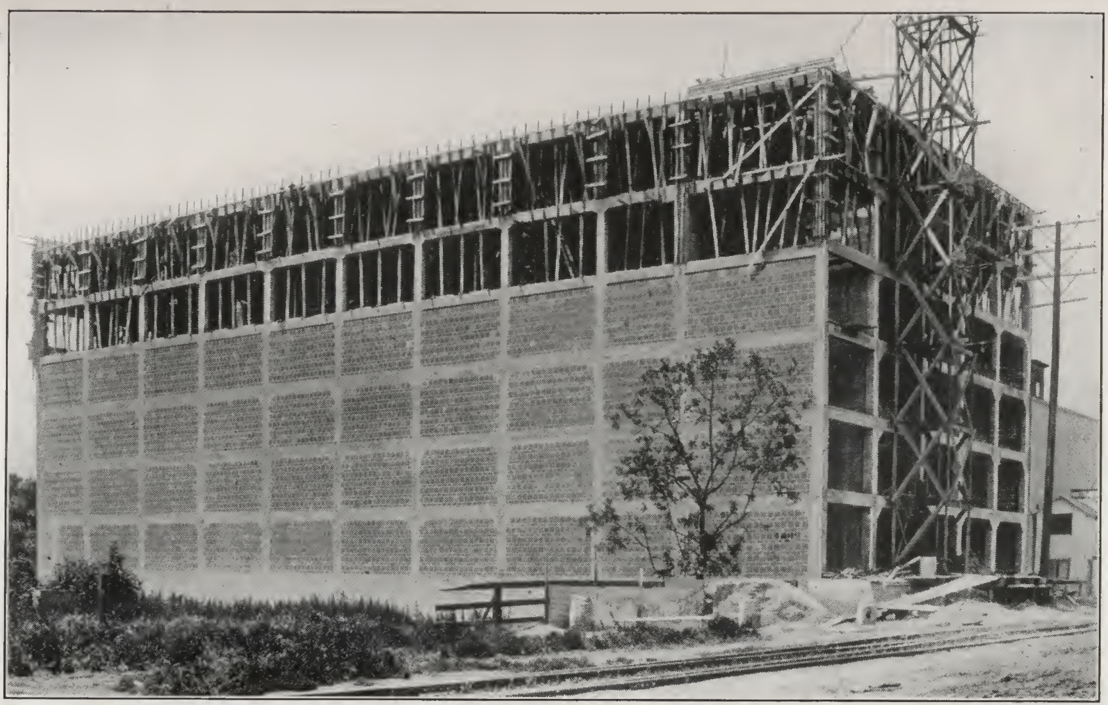
122. Factories and Warehouses.—In factories where very heavy loads do not occur, the same form of construction can be employed as for apartments and dwellings. Instead of interior tile partitions, however, steel columns and girders may be used. The outside walls can be made of hollow tile stuccoed, left with a smooth finish of the block showing, or veneered with brick.

Many of the latest types of factories and warehouses are built with a framework of reinforced concrete, consisting of posts, girders, and slab floors. After this framework is completed the spaces between the posts and girders on the outside walls are filled in with hollow tile as shown in Fig. 65. In this

Courtesy of National Fire Proofing Co., Pittsburgh, Pa. FIG. 62

Courtesy of National Fire Proofing Co., Pittsburgh, Pa. FIG. 63

Courtesy of National Fire Proofing Co., Pittsburgh, Pa. FIG. 64



Courtesy of the Denison Interlocking Tile Corporation, Cleveland, Ohio FIG. 65

Courtesy of the Denison Fire-Proofing Co., Mason City, Iowa FIG. 66

Courtesy of the Denison Fire-Proofing Co., Mason City, Iowa Fig. 67

case **T**-shaped, or Denison Interlocking, tile has been used. This filling-in is much lighter than brickwork and consequently does not require such heavy posts and girders to support it.

123. Office Buildings.—In tall office buildings, the framework is usually of steel, although in smaller buildings a reinforced framework is sometimes used. A considerable saving in weight and in the size and cost of the frame can be made by using hollow terra-cotta tile for filling in the walls between the columns and girders. These walls can, if desired, be veneered, or faced, with 4 inches of brickwork.

124. Railroad Stations.—An example of a railroad station built of Denison **H** tile is shown in Figs. 66 and 67. In Fig. 66 a stone base course and string-course are shown with a band of face brick between them. Above this is a hollow-tile wall. The windows are trimmed with face brick. The corners have a finish of face brick. Stone brackets and wooden brackets are built into the walls and the wall is ready for plastering. The finished building is shown in Fig. 67 and illustrates the possibilities of the use of hollow tile.

FIREPROOFING OF BUILDINGS

Serial 1061-2 Edition 2

INTRODUCTION

GENERAL DISCUSSION

1. Fireproofing a building means building it of materials that will prevent, as far as possible, its destruction by fire. The materials used may form the supporting members of the structure or they may be the covering applied to protect these members from injury by fire. A fire that may start in the contents of such a building may develop great heat, but it should not seriously injure the building. The construction employed to obtain this result is generally known as *fireproof construction.*

A building is said to be of fireproof construction when its walls, partitions, floors, and roof are built of fireproof materials, when its steel or iron structural members are protected from the effects of fire by a covering of fireproof materials, and when the stairs, doors, door frames, window frames, sash, and casings are formed of incombustible materials that do not require to be covered by a fireproof covering.

2. Building Laws.—The building laws of most large cities contain detailed descriptions of the materials and forms of construction that may be used in fireproof construction within those cities. These materials and forms of construction are described in this Section. The architect or contractor should always familiarize himself with the specific requirements of the building laws of any city in which he wishes to do

business before beginning to design or construct a fireproof building.

3. Reasons for Making Buildings Fireproof.—In the United States, where the vast majority of buildings are built of wood, the annual loss of life and property by fire is enormous. Entire cities have been almost wiped out, with appalling losses of life and property. Such calamities could not happen if all buildings were of fireproof construction. Cities are therefore placing more and greater restrictions upon the erection of inflammable buildings within their limits, so as to prevent, as far as possible, the spread of fire from one building to other buildings in the neighborhood.

Notwithstanding these efforts on the part of municipal governments, the percentage of buildings that are of entirely fireproof construction is extremely small. Many buildings in cities have, however, partial protection from fire, such as masonry walls and fireproof roofs, which prevent the building from catching fire easily from the outside. There are, however, only too many cases where the interior construction of these buildings is of wood, which makes the interior of the building easily destructible by fire.

4. The principal reason why all buildings are not made of fireproof construction is that it costs much more to build them fireproof than otherwise. As long as this is the case, there will always be a great temptation to build non-fireproof or only partially fireproofed buildings. This is shown by the character of the buildings that are erected at the present time.

5. There are many good reasons why all buildings should be of fireproof construction. The principal reason is to prevent loss of life through fires. Cases are on record where many lives have been lost through the destruction, by fire, of factories, schools, theaters, hospitals, etc. Buildings such as these should always be made thoroughly fireproof, although frequently they are not.

The loss in property, by fire, is enormous and this is another excellent reason for making buildings fireproof. The destruction of a building by fire means an actual loss, even though the

value of the building and its contents are covered by insurance, as the material that entered into the construction of the building, as well as the contents of the building, has been destroyed. Even when a building is insured, the money received from the insurance company rarely covers the full actual loss, for during the time required to rebuild the building that has been burned, there is additional loss due to the interruption of the business that may have been carried on in the building. Much of this material and financial loss could be avoided if all buildings were of fireproof construction.

6. It should be remembered, however, that fires may occur in fireproof buildings when these buildings are filled with inflammable materials, and a serious fire in the contents of a building may interfere with the use of the building for a considerable time. The building itself, however, will not be destroyed and can again be put into a useful condition. A fireproof building will sometimes have a severe fire on one floor without affecting the floors above or beneath. Instead of spreading through the entire building and destroying it, the fire is confined within small limits by means of fireproof partitions, floors, ceilings, and the fireproofing that protects the steel structural parts of the building.

7. There are certain conditions under which it should be imperative that buildings be of fireproof construction. All buildings in the congested, or closely built, portions of cities should be of fireproof construction to prevent a fire in one building from spreading to those adjoining and causing a general conflagration. All school, office, factory, or other buildings that are over two or three stories in height, in which large numbers of persons are gathered or employed, should be of fireproof construction to prevent the possibility of a great loss of life through the destruction of the building or the inability of the occupants to leave the building safely while a fire is in progress.

8. Where capital is invested in a building with the view of securing a continuous and permanent revenue, the structure should always be of fireproof construction. The advantages of

this construction over other forms are that it is more permanent, the materials that enter into the building are more durable, and the cost for repairs is also small; also, the Fire Underwriters ask a lower rate, or premium, for insurance on buildings of this character. These items justify the greater initial expenditure that is required for this construction over less expensive forms.

9. Definitions of Terms.—Certain terms are used in connection with the discussion of fireproof buildings, and definitions of these terms are here given in order that their meaning may be understood as they occur in the following pages.

Conductors of heat are materials through which heat passes more or less freely. Steel and iron are materials of this character.

Non-conductors of heat are materials that do not permit heat to pass through freely; in such materials the part that is exposed to heat may have a high temperature, but this temperature decreases rapidly in the parts that are more distant or less exposed. All burned-clay products, concrete, plaster, and stone are non-conducting materials.

Combustible materials are those which may be entirely consumed by fire, such as wood.

Incombustible materials are those which can not be consumed by fire although they may be changed in form or even melt and their usefulness thus be destroyed. Steel and iron are materials of this character.

Fireproof materials are those which can not be consumed by fire and are non-conductors of heat. Burned-clay products and cement concrete are considered as fireproof materials and consequently are used to enclose and protect the incombustible materials that are essential to fireproof construction.

Fire retardant is a term used to describe any material or construction that tends to retard a fire and thus prevent it from reaching another part of the building or adjacent buildings.

Insulation is the placing of an incombustible or a fireproof material around a material that is affected by heat, to protect it from fire.

PRINCIPLES OF FIREPROOFING

10. General.—It is well known that steel and iron possess great strength and that they will not burn, but when used for structural purposes they are not fireproof materials. There is slight danger of steel beams and columns being melted by the heat of a burning building, but they may become hot enough to soften and fail when carrying a heavy load.

On the other hand, burned-clay products and concrete, while not possessing the strength of steel, are in the highest sense fireproof. The principle underlying fireproofing in general is, therefore, to encase or enclose all steel work that constitutes the supporting members of the structure, with a fireproof material, such as brick, terra cotta, or concrete, so that fire cannot reach this steel work or the heat from a fire affect it sufficiently to impair its strength.

Another principle is illustrated in the use of steel or iron in positions where they carry no loads. Steel or iron in the form of window and door frames, casings, sashes, and doors is in the highest sense fireproof. Under the heat of a fire such metals might expand, warp, or twist, but ordinarily they do not melt and they will retard the spread of the fire while adding nothing to the combustibles in the building.

11. Necessity for Steel and Iron.—As has been noted, steel and iron are not in themselves fireproof materials, yet they are absolutely necessary, in the construction of a fireproof building of any considerable height, to carry the loads. High fireproof buildings require a steel frame consisting of columns, girders, beams, trusses, etc., to furnish the necessary strength to support the loads that occur in the building and to support the protective enclosure of fireproof material that is fitted and attached to it.

Steel is also needed for reinforcing concrete which is used in fireproof construction. This steel is in the form of bars or of a heavy metal mesh which is buried in the concrete and is thus protected from fire.

FIREPROOF MATERIALS

12. Comparative Values of Fireproof Materials. There are several substances that can be used to protect steel. Their value depends upon the ability of the material to endure great heat for a length of time, as well as to withstand sudden cooling, which occurs when a stream of water from a hose is turned upon it. The value of various substances as fireproof materials is determined from time to time by laboratory tests, and the results of these tests are published by the National Board of Fire Underwriters. The following general facts may be stated as the result of these tests.

13. Brick, terra cotta, and **concrete** are the best and most extensively used fireproof materials. Burned-clay fireproofing tile is made with different degrees of density. That which is the least dense is considered the most effective material from the standpoint of fire protection but it is not so strong as the denser tile.

14. Brick is as good a material as can be found from the fireproofing standpoint. It has greater strength than tile and is correspondingly heavier.

15. Concrete, which is a mixture of cement and sand with stone, gravel, or cinders, is very often used, also concrete that is reinforced with steel. If the latter form is used, the reinforcing steel should be well embedded in the concrete to insure a proper protection against the effects of the heat, otherwise the steel will expand and cause the concrete to break and crumble.

16. Stone does not rank high as a fireproofing material. While it may not fail in a structural sense when exposed to fire, its surface is apt to be cracked and chipped off and its appearance ruined. Hence, in the reconstruction of a building which has been subjected to fire, the stone usually requires to be replaced with new material.

17. Ornamental terra cotta, like structural terra cotta, is not affected by the heat of an ordinary fire and is a very good material for the surface treatment of buildings.

18. Plaster of Paris is a better heat retardant than tile, but it softens under the influence of heat and disintegrates when water is thrown on it, consequently it is not used as extensively as tile.

19. Sheet metal, as has been suggested, is not fireproof, but it is a most valuable material as a fire retardant, and is used extensively for this purpose.

FORMS OF FIREPROOF CONSTRUCTION

20. Methods and Materials.—Different forms of fireproof construction are obtained by the use of the various fireproof materials just mentioned in connection with structural and reinforcing steel.

The exterior walls may be formed of brick, stone, concrete, terra-cotta tile, or terra cotta backed with brick, or of a framework of steel or of reinforced concrete filled in with brick, terra cotta, or concrete. The steel in the steel frame must be covered with fireproof materials.

The interior bearing members may be walls of masonry or a framework of reinforced concrete or of steel covered with fireproof materials. The floors may have a framework of steel, protected by fireproof materials, and the floor construction may be of brick, terra cotta, or reinforced concrete or the entire framework and floor may be formed of reinforced concrete.

The partitions may be of brick, concrete, terra cotta, or else of plaster of Paris in the form of blocks or of mortar which is applied to metal lath and studding; the stairs may be of reinforced concrete or iron, and the door and window frames, doors, sash, and casings of sheet metal. The foregoing materials can be combined in various ways to construct a fireproof building.

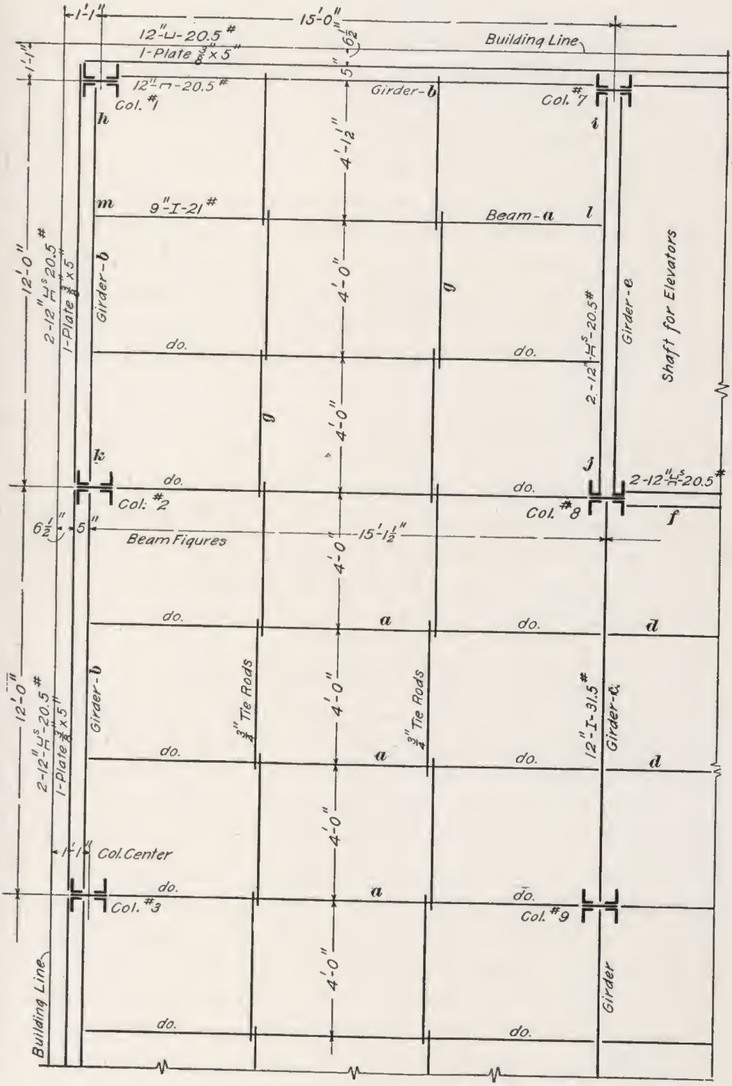
21. The construction of walls of the various materials enumerated, reinforced-concrete structures, steel framework of buildings, and cast-iron and sheet-metal work are subjects that are covered in other Sections.

Structures formed of reinforced concrete are in themselves fireproof, but, being described elsewhere, will not be discussed in this Section, which will be limited to the description of fireproofing as it is related to the protection of the steel members that form the framework of a building, the construction of tile arches and concrēte slabs which form the floors, the building of tile or metal lath and plaster partitions, and the use of some of the miscellaneous materials and forms of fire protection.

THE STEEL FRAME

22. Members of the Frame.—In order to understand the descriptions of the methods of fireproofing and of applying fireproof materials to steel work, it is necessary to have a knowledge of the names, locations, and purposes of the members that make up the steel frame, and also to be able to identify these members on a drawing. For large buildings a separate set of drawings is usually made which indicate the steel work only; such drawings are known as *framing plans*. These plans contain many indications that relate only to the steel work and which would be confusing were they shown on the regular plans. These framing plans are made in conjunction with the regular plans and require to be accurately drawn and the calculations carefully made to determine the size of the steel members that are required to carry the loads.

Three kinds of steel members that enter into nearly all steel-framed buildings are the *beams, girders,* and *columns.* The **beams** are the members that constitute the general floor framing and carry the floor arches or slabs. In Fig. 1, which shows a part of a floor framing plan, the beams are indicated at *a* and at *do.,* which is an abbreviation of the word ditto. Between the columns are members known as **girders,** shown at *b, c, e,* and *f*. The girders *b* are formed of two channels and are designed to carry part of the floor load and also part of the



Part of Floor Framing Plan

9

Fig. 1

weight from the outside wall of the building. At *c*, the girder consists of a single beam, which is larger than the regular floorbeam, as this girder is required to carry the floor load that comes from two of the floorbeams *a*, *a*, and also a similar load that comes from the floorbeams *d*, *d* of the adjoining panel. The girders *e* and *f* each consist of two members, these being required in order to carry a part of the floor loads and the masonry walls of the elevator shaft.

Where terra-cotta or brick arches are used between the beams, round steel bars, called *tie-rods*, are installed in the steel floor construction to prevent the beams spreading apart because of the thrust from these arches. Rods of this character are shown at *g*, *g*, Fig. 1, and are described later in this Section. The steel **columns** which support the girders and floorbeams are indicated by numbers *1*, *2*, *3* and *7*, *8*, *9*.

In Fig. 2 are shown in perspective the floor and ceiling framing and the supporting columns as they will appear after the steel is erected and before it is enclosed in fireproofing material, the beams, girders, and columns being designated by the same letters and numbers as in Fig. 1.

23. The steel frames of tall buildings consist of a series of floor panels or bays similar to those shown in Fig. 1 between the columns #1, #2, #7, and #8, but vary in size to meet the peculiar requirements of the design. The columns extend from the footings below the basement floor to the roof and vary in size according to the loads they carry. In tall buildings the fireproofing of the interior steel beams and girders, the placing of the floor arches, and the enclosing of interior steel columns, is usually started as soon as two or three stories of the steel frame have been completed and follows in this ratio until the entire structure has been fireproofed. As this fireproofing progresses, the exterior walls are erected and the columns and girders in these walls are encased, so that frequently the fireproofing of the lower stories is completed and walls, ceilings, and columns are being plastered even before the steel work of the top story has been erected. This method insures rapid construction and a consequent saving of time.

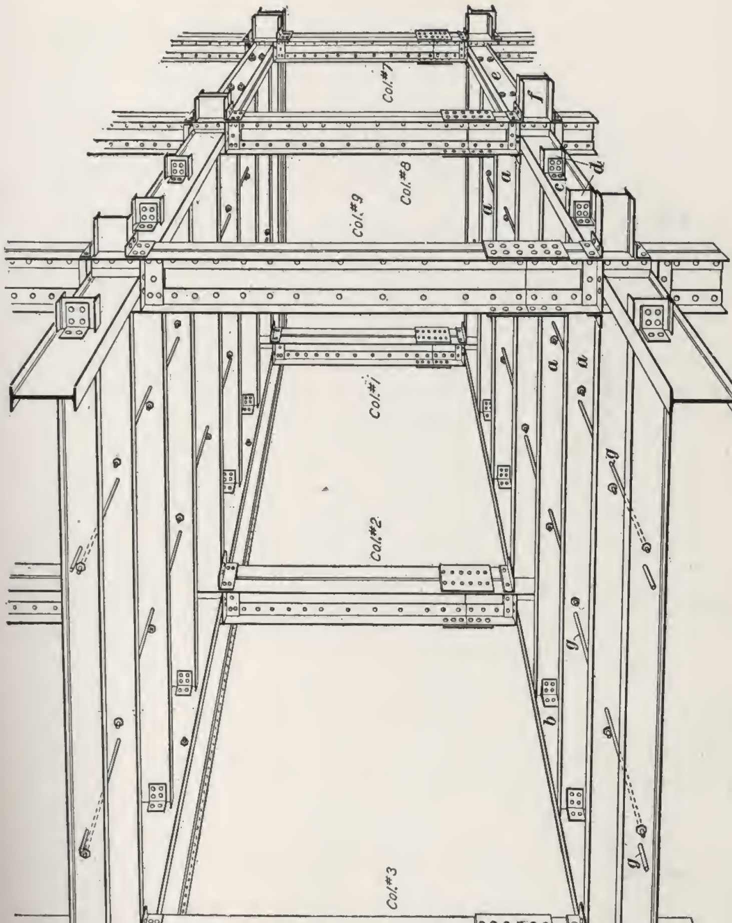


FIG. 2

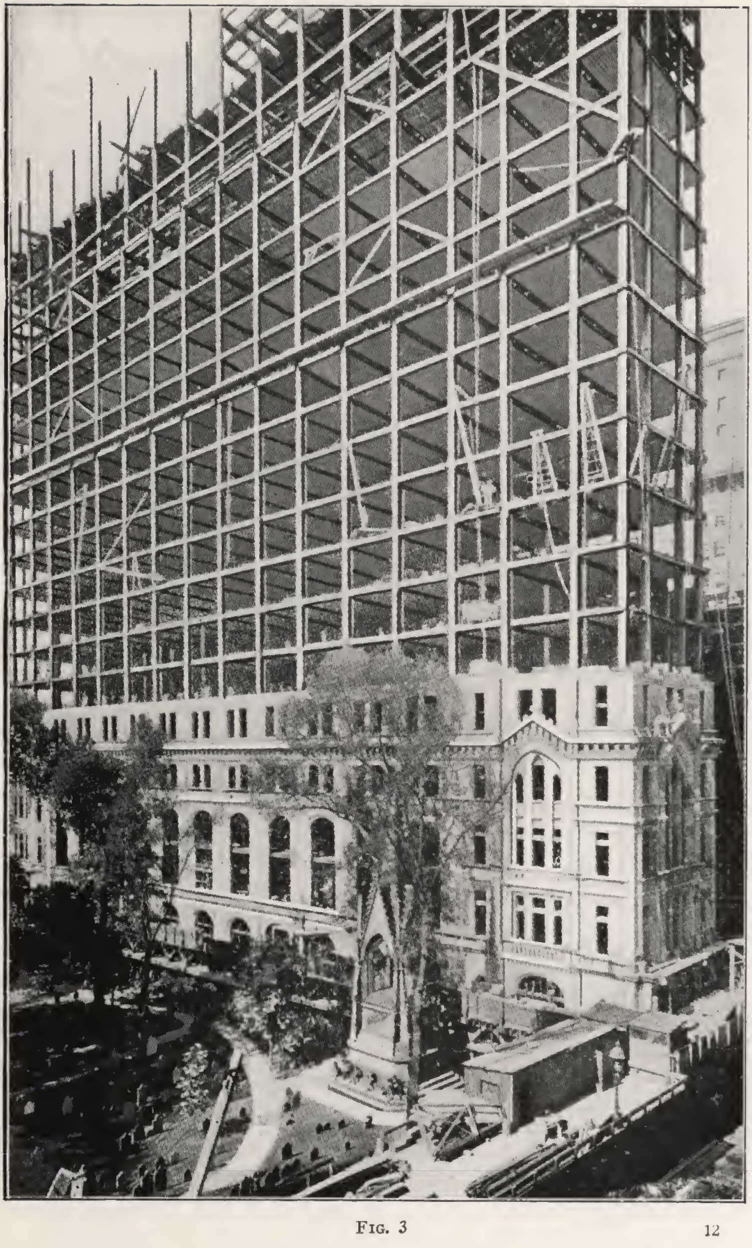


Fig. 3

In Fig. 3 is shown a steel-frame building which is under construction. The steel frame is shown to be incomplete at the top, the fireproofing of the floors has been installed to within a few stories of the finished part of the steel frame, and the exterior walls have been completed to the level of the sixth floor.

FIREPROOFING WITH TERRA COTTA

24. Kinds of Terra Cotta.—Terra-cotta fireproofing is made in different grades, *porous, semiporous* and *dense,* this difference being due in some cases to the process of manufacture. To make porous and semiporous terra cotta, some manufacturers mix a certain amount of sawdust with the clay and this is consumed in the process of burning the tile, thus forming small openings, or *air cells,* throughout the tile. The dense tile is made of clay or shale without any sawdust having been added to the mixture.

The grade of tile that is most generally used, however, is the *semiporous,* which is made of clay or shale. The porous nature is due to the character of the clay or shale that is used and also to the burning, the semiporous tile not being burned so hard as the dense grade.

The density of the tile is determined by the amount of water the tile will absorb. Some building codes stipulate that tiles shall not absorb over 10 or 12 per cent. of their weight of water.

25. Strength of Tile.—The strength of hollow tile that is of interest to the architect or builder is its strength in resisting compression, or crushing. This quality is important, as most terra cotta used for fireproofing is in compression. Hard-burned terra cotta will crush under a load of 4,000 to 5,000 pounds per square inch. As a safe working stress in terra-cotta floor arches, 500 pounds per square inch may be taken, as specified by the building code of New York City.

26. Construction.—When terra-cotta tile is used for fireproofing, the following methods of construction should be followered in the fireproofing of all beams, girders, and columns, and the forming of all floor arches and partitions:

Only cement mortar should be used for this construction, as lime mortar will not withstand the effects of the heat and water to which it might be subjected in case of a fire.

The edges of all tiles that are to adjoin each other should be well coated with the mortar and the pieces pushed together to insure that the mortar completely fills the joint. These joints should be carefully examined after the tiles have been set and any remaining openings should be closed with mortar so that the steel will not be exposed at these places.

It is well known that exposed edges and corners of materials are affected by fire more quickly than smooth flat surfaces, and for this reason all tiles should be placed in such a manner that smooth surfaces are obtained and projecting edges and corners avoided as far as possible.

FIREPROOFING OF GIRDERS AND BEAMS

27. Order of Procedure.—The usual order of procedure in fireproofing steel work is first to enclose the girders and such beams as project below the regular floor construction, then install the floor arches, and after the wood forms on which the arches are set have been removed, enclose the columns and build the partitions. The fireproofing of the steel will therefore be considered in that order, beginning with the girders.

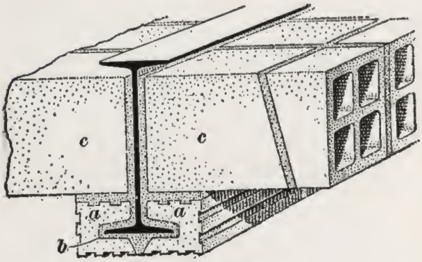


Fig. 4

28. Fireproofing a Single-Beam Girder.—One of the simplest forms of fire protection for a girder that is formed of a single large-sized **I** beam is shown in Fig. 4. The bottom flange of this girder is enclosed by two *clip tiles a,* which are held in place by the mortar *b* in which they are set. These clip

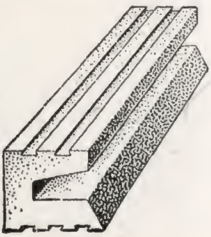


Fig. 5

tiles are solid in form and are shown in detail in Fig. 5. The floor tiles *c*, Fig. 4, rest directly upon the clip tiles and afford

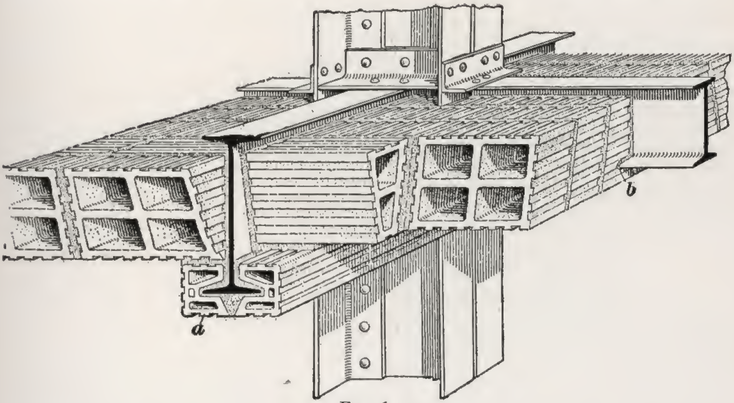


FIG. 6

protection to the web of the girder. The upper flange of the girder is protected by cinder concrete that is spread over the tops of the arches and floorbeams and beneath the finished floor, as will be shown further on.

A more elaborate form of clip tile is shown at *a* in Fig. 6 and in detail in Fig. 7. This tile has air cells in it which give it a greater fire-resisting value than that of the solid clip. The floor arches, as shown in Fig. 6, are supported upon the clip tile.

29. Fireproofing a Double I-Beam Girder.—A girder formed of two large **I** beams is illustrated in Fig. 8. The fireproofing consists of *clip tiles a*, which have already been described. On account of the width of the girder there is a space between the clip tiles that is filled in with a *soffit tile b*. The sides of the soffit tile are splayed, or beveled, and fit into the bevels of the clip tiles so as to form a good key. This prevents the soffit tile from dropping out. Resting upon the clip tiles, and supporting the floor tiles *d*, are *stretcher tiles c*, which are the size of a common brick. A detail of the soffit tile is shown in Fig. 9.

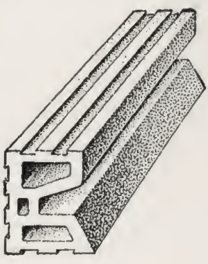


FIG. 7

30. Fireproofing a Box Girder.—Fig. 10 shows a box girder and a method of fireproofing it. A soffit tile *a* which is of the same width as the bottom flange of the girder is held in place against the under side of the girder by means of metal clips *b* which enter holes in the sides of the soffit tile and are bent over the flanges of the girder. This tile is set in mortar. Angle tiles *c* are then bedded in mortar on the top of the lower flanges and keep the metal clips in place as well as form a bearing for the tiles *d*, which are standard partition tiles. The partition tiles protect the sides of the girder and the top is protected by a layer of cinder concrete.

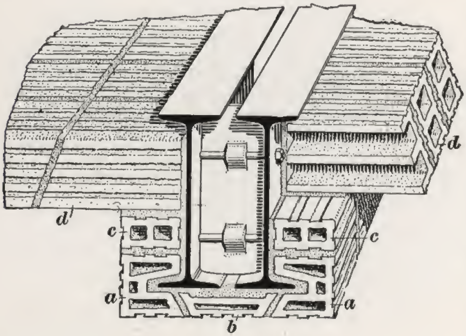


FIG. 8

31. Protection of Floorbeams.—Floorbeams are fireproofed on the lower flange in the same manner as **I**-beam girders, that is, by the use of clip tiles. This method is employed when the floor arch is at the top of the beam and the beam projects below the under side of the arch. When, however, the lower flange of the beam is above the bottom of the arch, as shown at *b* in Fig. 6 and *e* in Fig. 10, the floor tiles are made with projections that extend beneath the **I** beam and cover the lower flange of the beam. When the flange of the **I** beam is wide, a soffit tile as shown in Fig. 11 at *d* is used. The *skews a* are set in mortar against the webs of the **I** beams. The sides of floorbeams are thus protected by the skew of the floor construction and the tops of the beams by a layer of cinder concrete, or cinder fill, shown at *h*.

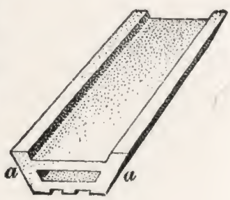


FIG. 9

FLOOR CONSTRUCTION OF TERRA COTTA

32. Types of Floor Construction.—Terra-cotta floors are formed of units or blocks, which are assembled on wooden forms and cemented together to form the various systems of floor construction shown in the illustrations which follow.

Terra-cotta floor construction may be of two forms, flat or curved. There are several varieties of the flat form, known as the *flat arch,* the *Johnson system,* the *combination system,* etc.

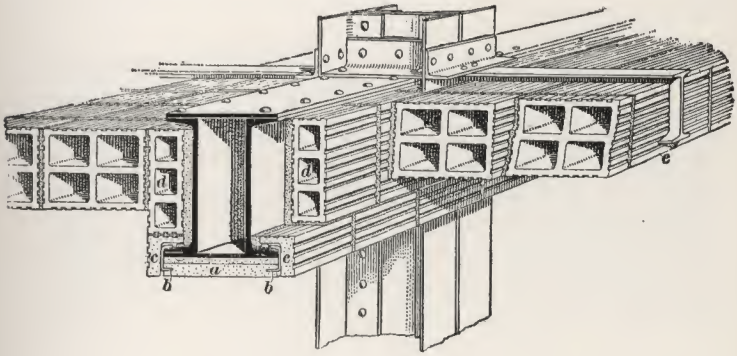


FIG. 10

The curved floors are represented by the *segmental arch* and the *Guastavino* system.

Arches or floor systems are also divided into two groups, known as long-span and short-span. A short-span arch or system is one which spans the space between the beams which divide a panel such as *h i j k* in Fig. 1 into narrower sections as shown at *h i l m*. A long-span arch or system is one that fills an entire panel such as *h i j k* when the panel is not divided by intermediate beams such as *m l*. The span of a short-span arch may be from 3 feet to 10 feet but is usually from 4 to 6 feet. A long-span arch or system generally springs from girders and walls, while a short-span arch is placed between intermediate beams or between these beams and the girders and walls.

In some cases a long-span flat system may be supported on all four sides by being reinforced in both directions. More often, however, the reinforcement runs in one direction only.

FLAT ARCHES

33. The flat arch, as the name implies, is flat on the top and bottom. The blocks have sloping sides so that when they are assembled and the middle block, called the *key,* is put in place, an arch is formed which spans the distance between the bearings. There are three types of flat arches, which are named after the arrangement of the blocks in the arch: the *side-con-*

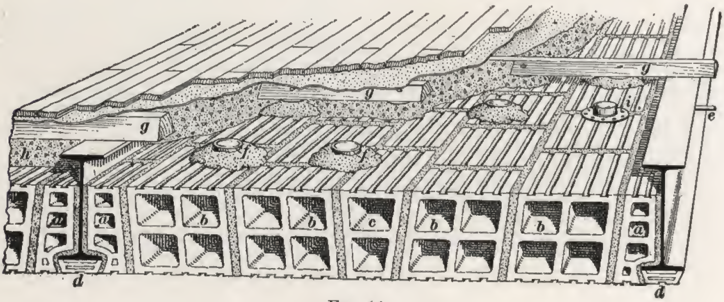


FIG. 11

struction arch, Fig. 11, the *end-construction arch,* Fig. 12, and the *combination side and end construction arch,* Fig. 13.

34. Side-Construction Flat Arches.—In Fig. 11 is shown in perspective a flat arch of the side-construction type. By side construction is meant that the tiles are laid with their cells running parallel with the steel beams. The tiles *a,* which rest against the **I** beam, are known as *skews* or *skewbacks.* The tiles *b,* which form the body of the arch, are known as *lengtheners.* In the center of the arch is the *key c.* Standard lengtheners are made about 12 inches in size, measured perpendicularly to the beams. Lengtheners are also made in smaller sizes, such as 3 inches, 6 inches, and 9 inches, so that variations in the span of the arch can be taken care of. Thus, one arch may have a span that will take full-size lengtheners, while an adjacent arch may be 6 or 9 inches wider and will

require a 6-inch or 9-inch lengthener to complete the arch. In this case the key will be at one side of the center of the arch.

The thickness or depth of flat arches of the side construction and the loads they will safely carry for different spans are given in Table I. The widest span permissible for each of the various depths of arches used in floor construction is indicated by cross lines in the columns. Loads that will be supported by longer spans are given below the lines, but such spans should be used only for ceiling construction, and a floor load should not be placed upon them.

The loads given in the table represent the gross loads, except

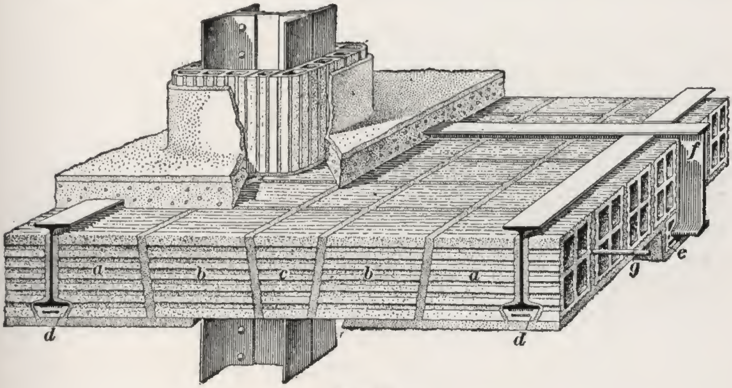


Fig. 12

that the weights of the arch tiles have been deducted. To obtain the safe live loads, the weights of the cinder filling, flooring, and plastering must be deducted. Cinder concrete weighs about 60 pounds per cubic foot; $\frac{7}{8}$-inch maple flooring, $3\frac{1}{2}$ pounds per square foot; $2'' \times 4''$ sleepers with cinder filling between, $8\frac{1}{2}$ pounds per square foot; and plaster applied to the under side of the arch tile, 5 pounds per square foot. The tie-rod shown at *e*, Fig. 11, wooden grounds at *f*, wooden sleepers *g*, concrete filling *h*, and the floor finish shown in this illustration will be described further on

35. End-Construction Flat Arches.—In end-construction flat arches, as shown in Fig. 12, the cells in the tiles run crosswise from beam to beam instead of parallel with the

beams, as in the side construction. The chief advantage of this form of arch is that it possesses about fifty per cent. more

TABLE I

SAFE LOADS FOR SIDE-CONSTRUCTION FLAT ARCHES

(Materials, semiporous. Factor of safety, 7. National Fire Proofing Co.)

Depth of Arches	6 Inches	7 Inches	8 Inches	9 Inches	10 Inches	12 Inches	15 Inches
Weight of Arch per Square Foot	26	29	32	36	38	44	54
Span Feet and Inches	Pounds per Square Foot	Pounds per Square Foot	Pounds per Square Foot	Pounds per Square Foot	Pounds per Square Foot	Pounds per Square Foot	Pounds per Square Foot
3–0	439	515					
3–3	370	434	500				
3–6	314	371	427	509			
3–9	270	320	368	439	514		
4–0	234	276	319	382	448		
4–3	204	243	280	335	393	543	
4–6	178	213	246	296	347	480	
4–9	158	188	218	262	308	427	549
5–0	140	167	193	233	275	382	491
5–3	124	149	173	209	246	343	442
5–6		133	155	188	221	309	399
5–9		118	139	169	200	279	362
6–0		107	125	153	181	253	329
6–3			113	138	164	231	300
6–6			102	125	149	210	274
6–9			92	114	136	192	251
7–0				104	124	176	231
7–6				86	104	148	196
8–0					87	126	167
8–6						107	144
9–0						91	124
9–6						78	107

strength than an arch of the side construction having the same weight and depth. Owing to this fact almost all of the arches

now built are of the end construction or of a combination of side and end construction.

In the end construction, shown in Fig. 12, the skewbacks *a* are similar in shape to the adjoining lengthener blocks *b*, with the exception that the ends of the skewbacks are square and the lower parts are cut out to fit around the steel beam. A key block *c* is required for the arch, and soffit tiles *d* of the hollow form are placed under the beams. In this illustration are also shown the clip tile *e*, which has been applied to the steel girder *f*, and a tie-rod at *g*.

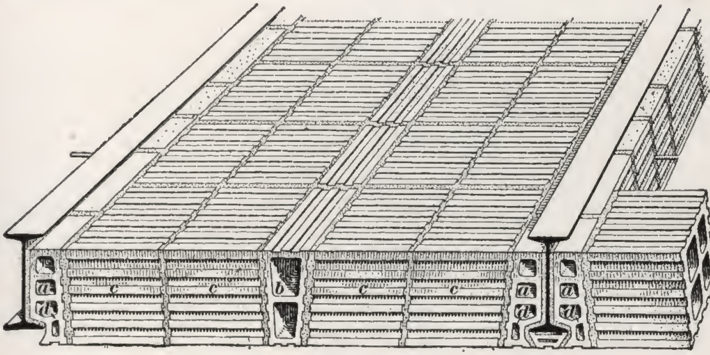


Fig. 13

36. Combination Side and End Construction Flat Arches.—One serious objection to end skewbacks is the lack of protection they afford the web of an **I** beam, particularly if the lip of the tile or the soffit tile which protects the lower flange of the beam is broken away, as the heat and flames can then reach the side of the beam, thereby weakening it more rapidly. To overcome this defect and still retain the strength and other good features of end construction, combination arches, as shown in Fig. 13, are formed of heavy side-construction skews *a*, side-construction keys *b*, and end-construction lengtheners *c*. End keys are stronger than side keys and are sometimes used when keys of greater length than 6 inches are required. By using side skews, the side of the beam is protected by the mortar in which they are bedded and by the webs of the skews, so that the entire skew would have to fail and

TABLE II

SAFE LOADS FOR END-CONSTRUCTION AND COMBINATION-CONSTRUCTION FLAT ARCHES

(*Materials, semiporous. Factor of safety, 7. National Fire Proofing Co*)

Depth of Arches	6 Inches	7 Inches	8 Inches	9 Inches	10 Inches	12 Inches	15 Inches
Weight of Arch per Square Foot	26	29	32	35	38	42	50
Span Feet and Inches	Pounds per Square Foot	Pounds per Square Foot	Pounds per Square Foot	Pounds per Square Foot	Pounds per Square Foot	Pounds per Square Foot	Pounds per Square Foot
3-0	482						
3-3	410	525					
3-6	354	453	563				
3-9	308	394	491	597			
4-0	271	347	431	525	627		
4-3	240	307	382	465	555		
4-6	214	274	341	414	495		
4-9	192	246	306	372	444	608	
5-0	173	222	276	336	401	548	
5-3	157	201	250	304	364	497	
5-6	143	183	228	277	331	453	
5-9	131	168	208	254	303	415	614
6-0		154	191	233	278	381	563
6-3		142	176	215	256	351	519
6-6		131	163	198	237	324	480
6-9			151	184	220	301	445
7-0			140	171	204	280	414
7-6			122	149	178	243	360
8-0				131	156	214	317
8-6				116	138	190	281
9-0					123	169	250
9-6						152	225
10-0						137	203
10-6						124	184
11-0							167
11-6							153

break away before flame could reach the side of the **I** beam. The points of greatest pressure in a flat arch are near the top of the keys and at the bottom of the skewbacks. To withstand this stress, skewbacks require a reinforcing web as shown at *d*. The absence of a reinforcing web at this place is very apt to cause the arch to fail.

37. The weight, depth, and safe load of end-construction and combination-construction flat arches can be found in Table II. The widest span permissible for each of the various depths of arches used in floor construction is indicated by the cross lines in the columns. Loads that will be supported by longer spans are given below these lines, but such spans should be used only for ceiling construction, and a floor load should not be placed on them.

The weights of the arches have not been deducted from the safe loads in this table, therefore the weight of the tile, cinder filling, flooring, and plaster must be deducted to obtain the safe live load for any arch and span.

38. A rule that applies to all three forms of flat arches just described is that the deeper the tile, within reasonable limits, the stronger the arch they will make, and for the same depth of beam a lighter and cheaper floor is obtained by filling the space with tile of the full depth of the beams rather than with other filling such as cinders or concrete. For instance, a 12-inch hollow-tile arch will weigh less and cost less per square foot than a 10-inch-tile arch with 2 inches of concrete filling on top of it.

39. Building-Ordinance Requirements.—While the loads in Tables I and II are safe as given, the thickness of the arch that may be used in certain large cities is regulated by the building laws. In determining the thickness of arch that is to be used in any building, the strength of the arch is not the only element to be considered, but, in addition, the building regulations should be consulted.

The ordinances of the city of Chicago require that "flat arch hollow tile or flat arch porous clay tile floor arches shall have a height of at least $1\frac{1}{2}$ inches for each foot of span."

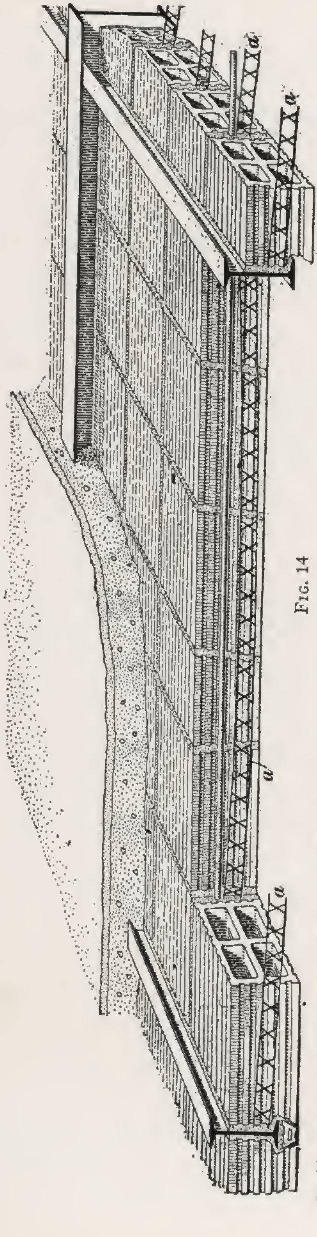


Fig. 14

The ordinances of San Francisco require that "flat arches shall have spans not exceeding 10 feet and the depth of the tile shall not be less than $1\frac{3}{4}$ inches for each foot of span."

The New York City laws require that "when terra cotta filling is in the form of flat arches, the depth of the blocks, unless reinforced with steel, shall not be less than $1\frac{1}{2}$ inches for each foot of span between steel beams, exclusive of the portion of the block projecting below the under side of the beams."

Thus, a flat arch of terra cotta for a span of 4 feet and projecting 1 inch below the lower flange of the **I** beams, would have to be made $1\frac{1}{2}\times4=6$ inches deep in Chicago, $1\frac{3}{4}\times4=7$ inches deep in San Francisco, and $1\frac{1}{2}\times4+1=7$ inches in New York City. If the arch projected 2 inches below the bottom of the **I** beam, it would have to be made 6 inches in Chicago and 7 inches in San Francisco, but would have to be 8 inches deep in New York City.

Tiles having depths of 11 inches, 13 inches, 14 inches, and above 16 inches are not manufactured, hence when this rule gives the sizes 11, 13, or 14 inches the next larger size must be used. For instance, if in designing terra-cotta flat arches according to rule

we find that the arch must be 13 inches in depth, it will be necessary to use 15-inch tile, as 13-inch and 14-inch tile are not manufactured.

40. Reinforced Flat Tile Arch.—In Fig. 14 is shown **a reinforced hollow-tile arch** that can be made much shallower than other flat arches, is light and comparatively inexpensive, yet strong. For a span of 6 feet other arches require a depth of 9 or more inches, while with this construction the depth needs to be only 6 inches. Arches of this depth and for this span are allowed to be used by many of the building departments for live loads of 150 pounds per square foot.

Arches of this form are adapted to wide spans with shallow beams or wherever a light, strong, sound-proof and fireproof floor is desired. This arch is of the end-construction form and the reinforcement consists of wire trusses placed in the joints between the tiles as shown at *a*. This reinforcement has a bearing on the lower flange of the steel beams and is bedded in cement mortar and is thus protected from the heat in case of fire. This wire-truss reinforcement is shipped to the building in reels and there cut into proper lengths as required.

41. Centering and Construction of Arches.—In Fig. 15 is shown the same part of the steel framework of a building that was previously illustrated in Fig. 2. In Fig. 15, however, the tile arches have been completed in the lower floor, as shown at *a*, and the section through one of the arches at *b* shows that it is of a combination side and end construction arch. The location of the tie-rods is shown at *c*. The lower flange of one of the wall channels *d* and the interior steel girder *e* have been covered with clip tile of the hollow form.

The ceiling of this story, or the floor above the completed one, has the wooden forms in place ready to receive the tile arches. These forms consist of timbers which span over several steel beams as shown at *f, f*, and corresponding timbers *g, g*, placed below these same beams and suspended from the upper members by means of rods *h*. On the timbers *g* are placed the planks *i* that form the floor on which the tiles are laid when constructing the arches.

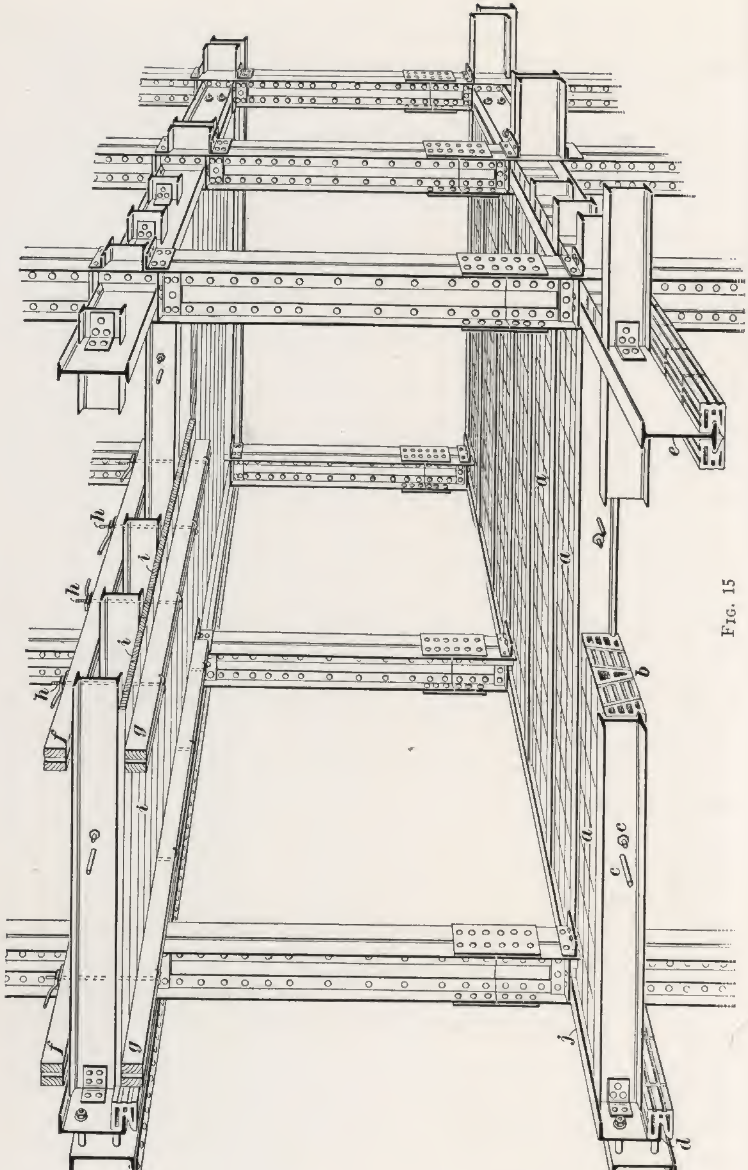


Fig. 15

The members *f* and *g* are formed of two $2'' \times 6''$ timbers that are separated by means of small blocks but otherwise secured together, and a space is thus formed between the timbers through which the rods may pass. The lower ends of these rods are bent to form hooks that will support the timbers *g*, and the upper ends are provided with threads, washers, and winged nuts, which permit of adjustments being made and of the forms being located at just the required height and level.

The arch is formed by placing the skewbacks first, then the lengtheners, and lastly the keys. After the mortar has become hard the winged nuts are unscrewed and the wooden floor and lower timbers of the forms are allowed to drop to the floor below, from which they are removed and taken to an upper story, there to be installed and used again in the same manner as described, the process being repeated until all floors have been completed. In this figure it will be noted that the channel *j* which forms part of the outside wall girder has been fireproofed before the forms for the floor construction are placed. The other channel of this wall will be enclosed in the masonry of the wall when it is built.

42. Tie-Rods.—In all arches, flat or segmental, a thrust is exerted against the steel beams, and tie-rods must be provided in the structural steel work to prevent the beams from spreading. Tie-rods are shown at *g* in Figs. 1 and 2.

In flat-arch construction the greatest thrust is at the top of the key and at the bottom of the skew of the arch. The tie-rods are placed preferably at a point about 3 or 4 inches above the bottom of the beams and are spaced according to the depth of the beam or the span of the arch.

The tie-rods are spaced not more than 8 feet apart; usually they are spaced at distances of eight times the depth of the beams. For flat tile arches with spans of 6 feet or less, $\frac{3}{4}$-inch tie-rods spaced about 5 feet apart are used; for 7-foot spans, $\frac{7}{8}$-inch rods spaced 5 feet apart, and for 9-foot spans, $\frac{7}{8}$-inch rods spaced 4 feet apart.

The thrust of segmental arches is considerable, and the line of the thrust is about the center of the skew. This would make

the most effective location for the tie-rods, near the bottom of the beams. They may be placed there and painted, but this exposes them to the heat from a fire and might cause the failure of the arches if the fire were a severe one. It is the general practice, therefore, to locate them where the material of the arch protects them from the heat of a fire, though this location may not be the most effective for resisting the thrust of the arch.

In constructing the arches, it is desirable to place the tiles so that a joint will occur at the tie-rods, and thus avoid the cutting of the tile to fit around the rod. Where this is not possible the cutting of the tile should be carefully done and the blocks repaired in such a manner that the arch will not be weakened by this operation.

43. Filling.—In a fireproof building, under no circumstances should the space between the top of the flat arch and the floor above, or the space above the haunches of segmental arches, be left open for the free circulation of fire. This space should be filled with cement concrete. Cinder concrete is commonly used for this filling, although for long-span arches gravel or fine-stone concrete is frequently used, as this will add to the strength of the arch.

44. Grounds and Sleepers.—In the filling are set sleepers made of wooden strips to which a wooden floor may be nailed. The sleepers are attached to the steel beams by means of clips, or they are attached to the floor construction by the use of spot grounds, as shown in Fig. 11 at *f*. These spot grounds are circular pieces of wood firmly secured to a metal collar, as shown at *i*. This collar is cemented to the top of the terra-cotta arches by strong cement mortar, the top of the ground being placed at the proper level.

SEGMENTAL ARCHES OF HOLLOW TILE

45. Characteristics of Segmental Arches.—The segmental arch is the strongest form of arch known. For this reason it is particularly adapted for floors of warehouses,

lofts, factories, or wherever great strength is required and a flat under surface or ceiling is not necessary. A standard form of construction of the segmental arch is shown in Fig. 16 (*a*). The skewbacks *a* are formed so that the upper part conforms to the shape and size of the arch block, while the lower part has a lip similar to a clip tile, to hold the soffit tile shown at *b*. This form of construction thoroughly fireproofs the steel work but requires a beam finish in the ceiling, as well as curved surfaces between the beams.

Fig. 16 (*b*) shows skews that are used in connection with segmental arches when a flat ceiling is desired. These skews

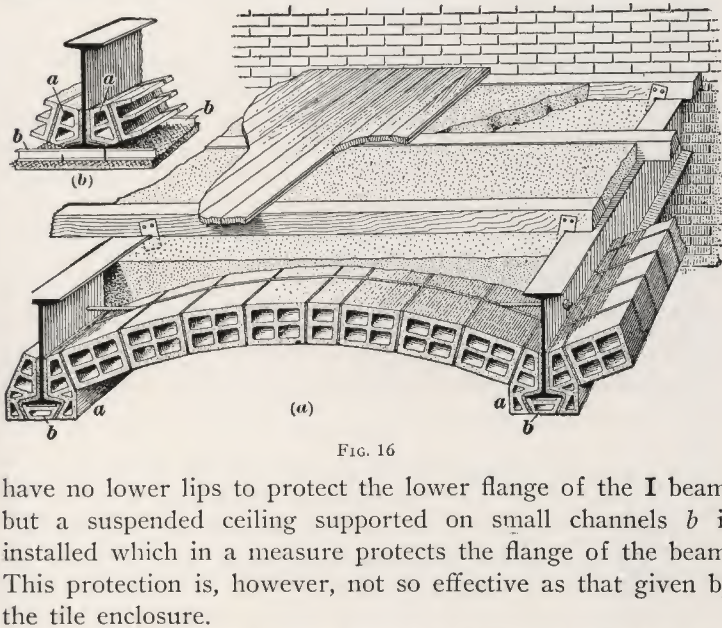


FIG. 16

have no lower lips to protect the lower flange of the **I** beam, but a suspended ceiling supported on small channels *b* is installed which in a measure protects the flange of the beam. This protection is, however, not so effective as that given by the tile enclosure.

Six-inch or 8-inch hollow tiles are generally used for segmental arches. The 6-inch arch of side construction is the standard used for all ordinary purposes. The rise of the side-construction arch can be increased by increasing the thickness of the upper parts of the mortar joints.

The *rise* of the soffit of an arch above the springing line should be from one-tenth to one-eighth the span of the arch.

TABLE III—SAFE LOADS FOR SEGMENTAL ARCHES OF HOLLOW TILE, IN POUNDS PER SQUARE FOOT

Span Feet	Rise Inches	4-Inch Arch Pounds	6-Inch Arch Pounds	8-Inch Arch Pounds	10-Inch Arch Pounds	Span Feet	Rise Inches	4-Inch Arch Pounds	6-Inch Arch Pounds	8-Inch Arch Pounds	10-Inch Arch Pounds
4	¾	702	902	1,078	1,178	7	¾	394	508	606	662
	1	920	1,184	1,414	1,545		1	520	669	799	873
	1¼	1,155	1,485	1,774	1,939		1¼	648	834	996	1,089
	1½	1,353	1,740	2,079	2,272		1½	762	981	1,171	1,280
	1¾	1,545	1,986	2,373	2,593		1¾	876	1,127	1,346	1,471
	2	1,736	2,233	2,667	2,915		2	983	1,264	1,510	1,650
4½	¾	616	792	946	1,034	8	¾	341	439	525	573
	1	812	1,044	1,247	1,363		1	457	588	703	768
	1¼	1,020	1,313	1,568	1,713		1¼	562	724	864	944
	1½	1,196	1,539	1,838	2,009		1½	668	859	1,026	1,122
	1¾	1,381	1,775	2,121	2;318		1¾	767	987	1,179	1,288
	2	1,536	1,975	2,359	2,578		2	854	1,099	1,312	1,434
5	¾	551	709	847	926	9	¾	300	386	461	504
	1	744	957	1,143	1,249		1	403	518	619	677
	1¼	911	1,172	1,400	1,530		1¼	501	645	770	842
	1½	1,072	1,379	1,647	1,800		1½	590	758	906	990
	1¾	1,238	1,592	1,902	2,078		1¾	677	871	1,041	1,137
	2	1,379	1,773	2,118	2,315		2	759	977	1,167	1,275
6	¾	455	585	699	764	10	¾	267	344	411	449
	1	612	788	941	1,028		1	359	462	552	603
	1¼	753	969	1,157	1,265		1¼	447	576	688	751
	1½	898	1,154	1,379	1,507		1½	531	683	816	892
	1¾	1,022	1,315	1,570	1,716		1¾	610	784	937	1,024
	2	1,148	1,476	1,763	1,927		2	683	879	1,050	1,147

NOTE.—The weight of the arch tile has been deducted in table so that only the dead load of concrete fill, plastering, etc. must be deducted to obtain net live load.

TABLE IV—SAFE LOADS FOR SEGMENTAL ARCHES OF HOLLOW TILE, IN POUNDS PER SQUARE FOOT

Span Feet	Rise Inches	4-Inch Arch Pounds	6-Inch Arch Pounds	8-Inch Arch Pounds	10-Inch Arch Pounds	Span Feet	Rise Inches	4-Inch Arch Pounds	6-Inch Arch Pounds	8-Inch Arch Pounds	10-Inch Arch Pounds
	1	327	421	503	550		1	218	281	336	367
	1¼	404	519	621	678		1¼	274	353	421	460
11	1½	479	617	737	805	16	1½	325	419	500	546
	1¾	551	709	847	925		1¾	374	481	575	628
	2	617	794	948	1,036		2	420	540	645	705
	1	297	383	458	500		1	192	248	296	324
	1¼	370	477	569	622		1¼	240	310	370	404
12	1½	439	566	676	738	18	1½	287	370	442	482
	1¾	505	649	776	848		1¾	330	425	507	554
	2	565	727	869	949		2	371	477	570	623
	1	272	351	419	458		1	172	221	265	289
	1¼	339	437	522	570		1¼	215	277	331	361
13	1½	403	519	620	677	20	1½	257	330	395	431
	1¾	463	596	712	778		1¾	296	381	455	497
	2	521	670	801	875		2	332	427	510	558
	1	253	326	390	426		1	154	199	237	259
	1¼	315	406	485	530		1¼	194	250	298	326
14	1½	374	482	575	629	22	1½	232	299	357	399
	1¾	430	553	661	722		1¾	268	344	412	450
	2	481	619	740	808		2	301	377	462	505
	1	234	302	361	394		1	140	181	216	236
	1¼	292	377	450	491		1¼	177	227	272	297
15	1½	347	447	534	583	24	1½	211	272	325	355
	1¾	401	515	616	673		1¾	244	314	375	410
	2	449	577	690	754		2	274	353	421	460

NOTE.—The weight of the arch tile has been deducted in table so that only the dead load of concrete fill, plastering, etc. must be deducted to obtain net live load.

If the proportions are one-tenth, a 6-foot arch would require a rise of 7.2 inches, while with a ratio of one-eighth the rise would be 9 inches.

46. Long-Span Segmental Arch.—The *long-span fireproof floor construction* is a logical result of the effort to cut down the amount of structural steel required in a building without reducing the strength of the structure. The less the dead weight of the floor, the less will be the size, weight, and expense of columns, girders, and the general structure. Segmental floor arches have been successfully used for all lengths of spans up to and including 25 feet. These arches are exceptionally strong, but they exert a great thrust upon the supporting beams between which the arches are sprung. To withstand this thrust, the outer bays of the floors sometimes have reinforced flat arches, and no tie-rods are used; in other installations the thrust is taken care of by steel tie-rods from beam to beam. Notwithstanding the strength of the long-span segmental arches, they are not used extensively, the more practical flat-arch combination system being preferred on account of giving a flat ceiling.

47. Safe Loads for Short-Span Segmental Arches. In Table III will be found the safe loads, in pounds per square foot, for segmental arches of various depths, built of semi-porous tile with $\frac{5}{8}$-inch webs and shells, of side construction and with various rises as indicated in the second column. A factor of safety of 7 is allowed. The spans covered by this table are from 4 feet to 10 feet, inclusive, which will include all ordinary short-span arches.

48. Safe Loads for Long-Span Segmental Arches. In Table IV are given the safe loads for segmental arches having spans from 11 to 24 feet, which will include all ordinary long spans.

GUASTAVINO ARCHES

49. Guastavino arches are formed of several layers of flat tile, so laid and embedded in cement mortar that they will form a solid shell-like construction when completed.

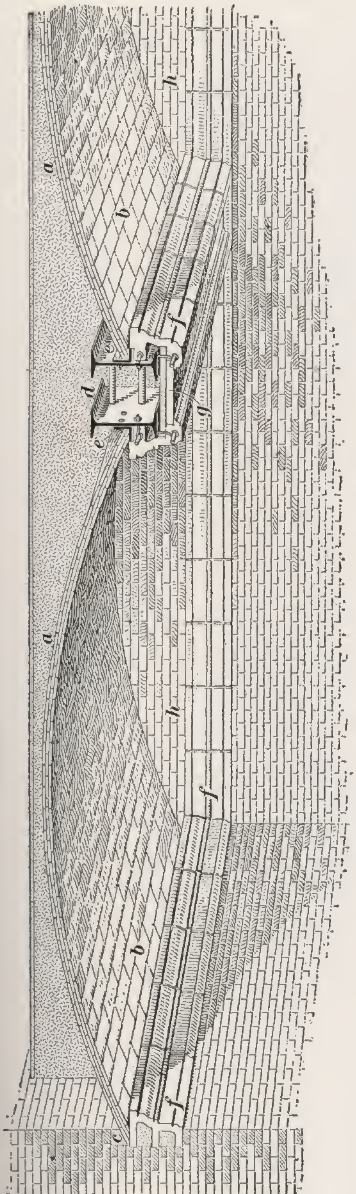


Fig. 17

The tiles are made of the same materials as regular dense terra-cotta fireproofing, with the exception that those intended for exposed ceilings are made in the various colors and textures that are possible in architectural terra cotta. These tiles are about 1 inch thick, 6 inches wide, and from 12 inches to 24 inches long, and the tiles of one layer break joints with those of the other layers, thus securing a bond.

50. In Fig. 17 are shown parts of two Guastavino segmental arches which are formed of three layers of tiles as above described. A section through the arches is shown at *a, a,* and the finished under side of the arches at *b*. One side of the arch springs from the wall of the building, a recess *c* being formed in the wall to provide a suitable bearing. Midway between these walls is the steel girder *d,* which is formed of two **I** beams. To these beams are attached angles *e,* from which the inner edges of the arches are sprung. A terra-cotta belt-course *f* is carried around

the walls to provide a suitable finish at the spring line of the arches, and members of the same form are used to enclose the steel girder, a soffit member *g* being provided to make a finished terra-cotta beam of this enclosure. Regular face brick are used for the walls of the building above the terra-cotta course at the ends of the arches, as shown at *h*.

51. Wooden forms are required in constructing these arches, and on these forms the first layer of tile is placed to form the design desired. If a ceiling construction is being formed, as is shown in Fig. 17, the tiles are spaced to provide uniform-size joints, and wooden wedges are placed in these joints to preserve this spacing. A heavy coating of cement mortar is applied to the upper surface of this first layer of tile and the joints between the tiles are thoroughly filled. While this mortar is still soft, the second layer of tile is laid and pressed into it, and this process is continued until the required number of thicknesses or layers has been laid.

When the arch has been completed and the mortar become set, the forms are removed, the mortar that has overlapped the tiles on the face *b* of the arch is cut away, and the joints are finished as desired.

These arches are used for floor, ceiling, and roof construction. They may be built in the form of single arches, vaults, or domes. The number of layers of tile required will depend upon the dimensions of the arch and the load it is required to carry. Floors built on this principle have been tested and found to carry very heavy loads. When such work is contemplated, however, the architect should consult with the representative of a company that erects these arches, as it is usual for such a company to determine what strength of construction is required to take the loads and thrusts from the arch, vault, or dome that is to be constructed.

LONG-SPAN FLOOR SYSTEMS

52. There are several floor systems in which terra-cotta tile is used, that are frequently referred to as arches. These systems are in no sense arches, as they are not built in accor-

dance with the principles of the arch. They are, however, popularly called floor arches, or flat floor arches.

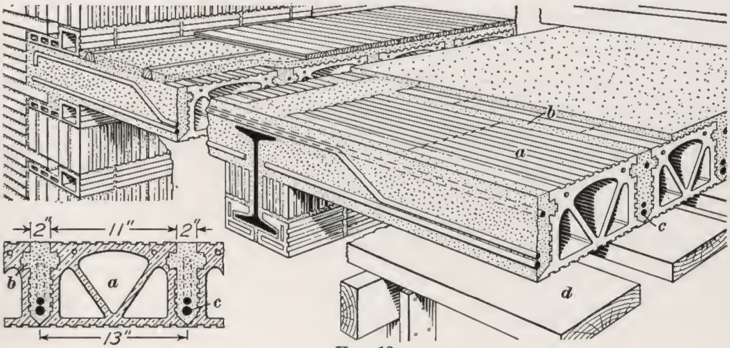


Fig. 18

53. Natcoflor System. — A long-span floor system, known as the Natcoflor system, is shown in Fig. 18. The floor consists of tile blocks *a* 13 in. wide, having recesses on the sides to include concrete beams *b* 2 in. wide, with rods *c*. The floor is built on a centering of 2-inch planks *d*. The weight of the floor per square foot is as follows: 4″, 28 lb.; 5″, 34 lb.; 6″, 39 lb.; 7″, 42 lb.; 8″, 45 lb.; 9″, 48 lb.; 10″, 52 lb.; 12″, 59 lb. In Table V is given a portion of a table showing the depth of

TABLE V

TILE DEPTH AND STEEL AREA FOR NATCOFLOR FLOOR

Span, Feet	Total Safe Load, Pounds per Square Foot											
	100		120		150		175		200		225	
	T	*S*	*T*	*S*	*T*	*S*	*T*	*S*	*T*	*S*	*T*	*S*
6	4	.16	4	.19	4	.23	4	.28	4	.31	4	.35
7	4	.21	4	.26	4	.32	4	.38	5	.32	5	.35
8	4	.28	4	.33	5	.31	5	.37	5	.42	5	.47
9	4	.35	5	.32	5	.39	5	.46	5	.53	6	.46
10	5	.33	5	.39	5	.48	6	.45	6	.51	6	.57
11	5	.39	5	.47	6	.46	6	.54	6	.62	7	.57
12	5	.47	6	.44	6	.54	6	.65	7	.61	7	.68
13	6	.43	6	.52	6	.64	7	.63	7	.71	8	.67
14	6	.50	6	.60	7	.61	7	.73	8	.70	8	.78
16	6	.65	7	.65	8	.67	8	.80	9	.79	9	.89
18	7	.68	8	.69	9	.74	9	.88	10	.89	10	1.00
20	8	.71	8	.85	9	.92	10	.97	12	.89	12	1.00
22	9	.75	9	.90	10	.99	12	.95	12	1.08		
26	10	.93	12	.90	12	1.12						

tile (T) and the area of steel (S) recommended by the National Fireproofing Co. for the loads and spans given.

54. Johnson-System Floor.—In Fig. 19 is shown the Johnson-system floor. This system consists of the regular form of tile as shown at *a*, and a reinforcement of steel in the form of wires *b* interwoven with larger wires *c* placed about 4 inches apart. These larger wires run straight from bearing to bearing. These floors can span a space of as much as 25 feet; they rest on bearings for support and exert no thrust as does an actual arch.

In constructing floors by this system, the steel-wire mesh is bedded in concrete, hollow-tile blocks are laid thereon, and the

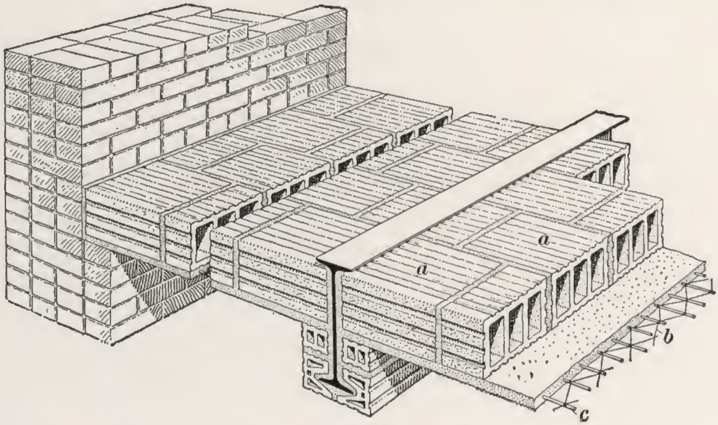


FIG. 19

wide joints between courses are filled with concrete. The arch shown in this illustration has no concrete on top of the tiles. In practice, floors are laid in this manner, but in some cases they have one, two, or more inches of concrete on top of the tiles. Adding 1 inch of concrete top finish adds about 50 per cent. to the strength of the arch, and adding 2 inches of concrete to the top of the tiles increases the strength of the arch over 100 per cent.

55. Safe Loads for Johnson-System Floors.—The safe loads for the Johnson-system floors, as given by the manufacturers, can be found in Tables VI and VII. These values

TABLE VI

SAFE LOADS FOR JOHNSON-SYSTEM FLOORS WITHOUT A CONCRETE TOP FINISH, IN POUNDS PER SQUARE FOOT

Area Reinforcing = Steel	12-Inch Tile .64 Square Inch	10-Inch Tile .57 Square Inch	9-Inch Tile .51 Square Inch	8-Inch Tile .47 Square Inch	7-Inch Tile .42 Square Inch	6-Inch Tile .38 Square Inch	5-Inch Tile .31 Square Inch	4-Inch Tile .25 Square Inch	3-Inch Tile .22 Square Inch
Span Feet	Weight of Floor per Square Foot, 55 Pounds	Weight of Floor per Square Foot, 52 Pounds	Weight of Floor per Square Foot, 48 Pounds	Weight of Floor per Square Foot, 45 Pounds	Weight of Floor per Square Foot, 42 Pounds	Weight of Floor per Square Foot, 37 Pounds	Weight of Floor per Square Foot, 35 Pounds	Weight of Floor per Square Foot, 29 Pounds	Weight of Floor per Square Foot, 27 Pounds
5	...	...	...	...	...	...	446	353	213
6	...	...	...	...	579	470	311	227	147
7	...	...	...	553	425	341	223	165	113
8	...	...	488	422	324	263	171	125	79
9	...	507	383	333	254	206	132	113	61
10	558	407	308	264	202	163	105	76	48
11	458	337	253	219	165	133	86	62	
12	386	282	210	179	137	111	71	51	
13	326	234	178	152	116	93	59		
14	278	202	152	129	98	78	49		
15	241	175	130	111	84	68	42		
16	210	151	113	97	73	58			
17	189	133	99	75	63	51			
18	164	117	87	72	56	45			
19	146	103	77	66	49				
20	129	92	68	58	43				
21	117	83	61	51					
22	104	75	54	46					
23	95	67	49						
24	86	61	44						
25	77	55							

TABLE VII

SAFE LOADS FOR JOHNSON-SYSTEM FLOORS HAVING 2 INCHES OF CONCRETE TOP FINISH, IN POUNDS PER SQUARE FOOT

Area Reinforcing = Steel	12-Inch Tile 1.0 Square Inch	10-Inch Tile .95 Square Inch	9-Inch Tile .90 Square Inch	8-Inch Tile .86 Square Inch	7-Inch Tile .82 Square Inch	6-Inch Tile .73 Square Inch	5-Inch Tile .68 Square Inch	4-Inch Tile .68 Square Inch	3-Inch Tile .6 Square Inch per Foot Width
Span Feet	Weight of Floor per Square Foot, 79 Pounds	Weight of Floor per Square Foot, 77 Pounds	Weight of Floor per Square Foot, 72 Pounds	Weight of Floor per Square Foot, 69 Pounds	Weight of Floor per Square Foot, 66 Pounds	Weight of Floor per Square Foot, 62 Pounds	Weight of Floor per Square Foot, 59 Pounds	Weight of Floor per Square Foot, 54 Pounds	Weight of Floor per Square Foot, 51 Pounds
7	...	...	...	...	...	...	...	...	569
8	...	...	...	...	...	...	...	567	437
9	...	...	...	...	...	...	568	442	342
10	...	...	...	...	...	530	435	354	272
11	...	...	...	...	514	435	355	292	224
12	...	...	572	508	429	365	298	242	187
13	...	568	487	428	364	310	255	204	157
14	...	491	417	368	311	265	215	174	
15	540	421	362	318	269	230	185	151	
16	470	368	317	278	236	200	162		
17	415	326	277	243	207	175	142		
18	368	287	245	215	182	155	125		
19	325	251	219	190	161	137			
20	292	228	195	170	146	121			
21	265	206	175	153	129				
22	238	185	160	139	116				
23	218	168	143	125					
24	196	153	130						
25	178	138							

are given for general information only, as each particular floor should be designed for the purpose for which it will be used. A factor of safety of 4 is allowed. It will be noted that the arch in Table VI has no concrete top finish, while the arch in Table VII has a 2-inch concrete top finish.

56. Combination Hollow-Tile and Reinforced-Concrete Floor Construction.—A long-span system of floor construction consisting of reinforced-concrete beams and hollow tile is illustrated in Figs. 20 and 21. The strength of this floor depends upon the reinforced-concrete beams shown at *a*, Fig. 20, and *f* in Fig. 21. The steel rods furnish the neces-

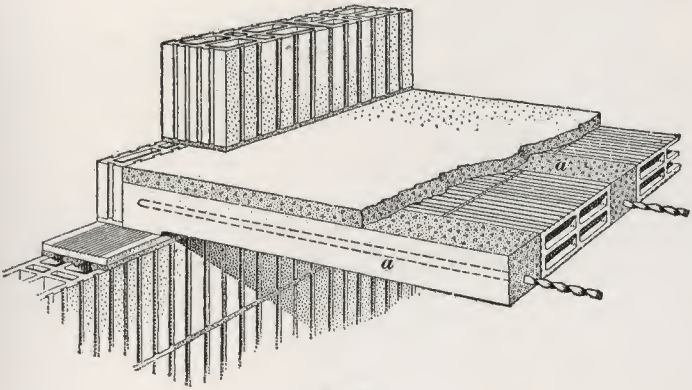


FIG. 20

sary tensile strength for these beams, and the tile makes a light floor construction. The strength of this type of floor can be varied to suit circumstances. Fig. 20 is the simplest form and is designed for use in residences and other buildings where the floor loads are light. Fig. 21 is a form that is designed to support heavy loads, and the reinforced beams contain two rods. One of these rods is bent up and carried over the tops of the **I** beams as shown. Still stronger beams can be made by making the beams deeper and adding more steel. The design of concrete beams will be taken up in the Section entitled *Design of Beams*.

57. The combination floor is built upon forms, consisting of posts *a*, Fig. 21, stringers *b*, and planks *c*. The planks are placed under the beams in such positions that the edges of the tiles *d* will rest on two adjacent planks. Rods are placed in the spaces between the tiles, and concrete is poured to fill these spaces. The rods must be kept off the plank so as to be entirely covered with concrete. After the pouring of the concrete has begun a man goes along with a rod having a hook on the end of it and slightly raises the reinforcing rods so that the concrete may flow beneath them. A layer of concrete 2 inches or so in

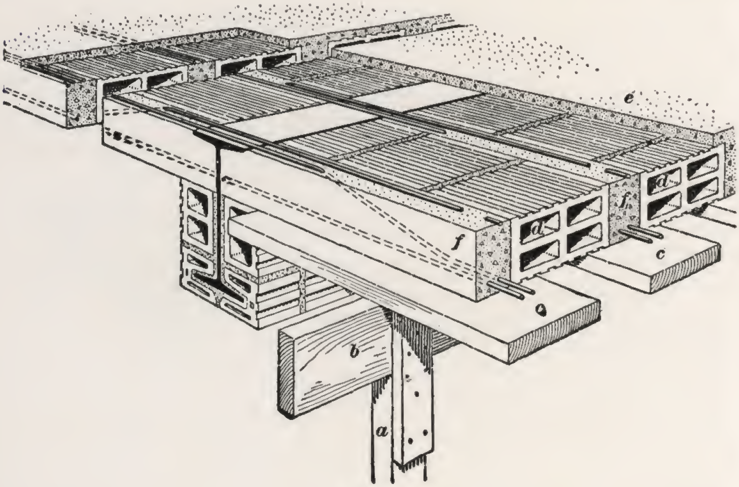


FIG. 21

thickness is poured over the top of the blocks and the beams, as shown at *e*. This layer of concrete adds greatly to the strength of the floor construction.

58. Combination floor systems are comparatively inexpensive on account of the economy of centering, and are desirable on account of having great strength combined with lightness. They are convenient for the plasterer on account of having three-fourths of their surfaces scored with dovetail grooves which form keys for the plaster, and the flat ceilings they present make them desirable for all kinds of buildings.

TABLE VIII

SAFE LOADS FOR COMBINATION REINFORCED CONCRETE AND HOLLOW TILE FLOORS, 2-INCH CONCRETE TOP FINISH, IN POUNDS PER SQUARE FOOT

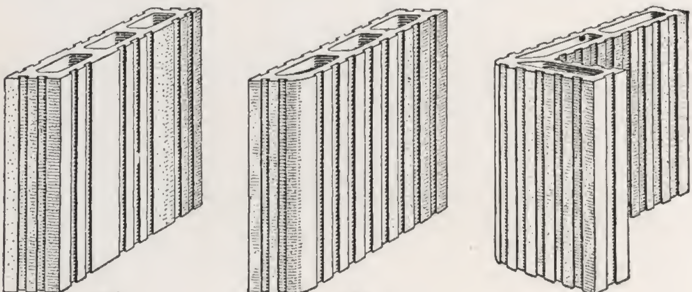
Span Feet	15-Inch Tile $1\frac{5}{16}$-Inch Diameter Rod	12-Inch Tile $1\frac{1}{4}$-Inch Diameter Rod	10-Inch Tile $1\frac{1}{4}$-Inch Diameter Rod	9-Inch Tile $1\frac{1}{8}$-Inch Diameter Rod	8-Inch Tile $1\frac{1}{8}$-Inch Diameter Rod	7-Inch Tile $1\frac{1}{8}$-Inch Diameter Rod	6-Inch Tile 1-Inch Diameter Rod	5-Inch Tile 1-Inch Diameter Rod	4-Inch Tile $\frac{7}{8}$-Inch Diameter Rod
	Weight of Floor per Square Foot, 106 Pounds	Weight of Floor per Square Foot, 92 Pounds	Weight of Floor per Square Foot, 82 Pounds	Weight of Floor per Square Foot, 76 Pounds	Weight of Floor per Square Foot, 72 Pounds	Weight of Floor per Square Foot, 67 Pounds	Weight of Floor per Square Foot, 62 Pounds	Weight of Floor per Square Foot, 54 Pounds	Weight of Floor per Square Foot. 50 Pounds
5	7,024	5,226	4,488	3,289	2,988	2,623	1,801	1,361	934
6	4,849	3,598	3,088	2,264	2,053	1,798	1,228	930	634
7	3,534	2,608	2,248	1,640	1,488	1,305	890	669	452
8	2,680	1,983	1,702	1,239	1,023	983	657	500	334
9	2,094	1,548	1,328	974	872	765	513	383	254
10	1,678	1,236	1,060	766	693	605	404	300	196
11	1,368	1,004	862	619	560	489	323	238	153
12	1,134	830	711	508	459	399	262	192	120
13	949	696	593	421	381	331	214	155	95
14	804	586	500	353	318	276	176	126	59
15	686	499	425	298	268	231	145	103	46
16	591	427	364	253	227	195	120	84	35
17	511	368	313	215	192	166	99	78	26
18	444	312	270	184	164	140	83	54	18
19	388	276	234	157	140	119	67	44	12
20	340	240	203	134	119	101	54	35	6
21	298	209	177	115	101	86	44	26	
22	263	183	154	98	86	72	34	19	
23	231	159	134	83	73	61	27	7	
24	204	139	126	70	61	50	19		

The safe load, in pounds per square foot, for this type of long-span flat arch, having 2 inches of concrete top finish, can be found in Table VIII. The factor of safety used is 4.

59. Two-Way Systems.—There are long-span systems formed of reinforced beams and hollow tile in which the beams run in two directions at right angles to each other and the blocks are held between the beams. These systems can be made very strong so as to span a distance of 25 or 30 feet. This economizes in the number of intermediate steel beams or reinforced-concrete beams that will be required. Special forms of tiles are used to close up the open ends of the regular tile so that the concrete will not enter them.

FIREPROOFING STEEL AND IRON COLUMNS WITH TERRA COTTA

60. General.—As the stability of a building in case of fire depends upon the protection of the columns from failure, the greatest care should be exercised to see that they are adequately fireproofed with good non-heat-conducting materials,



(a) (b) (c)

Fig. 22

and also protected from corrosion. Hollow tile is the best burned-clay product to use for enclosing the columns, and if the outside face of the tile is plastered, an additional protection is obtained. The tile should be at least 3 inches thick and be laid with the vertical joints broken to secure a good bond. The

space inside of the tile enclosure of the column should be filled with concrete, as this material not only protects the column

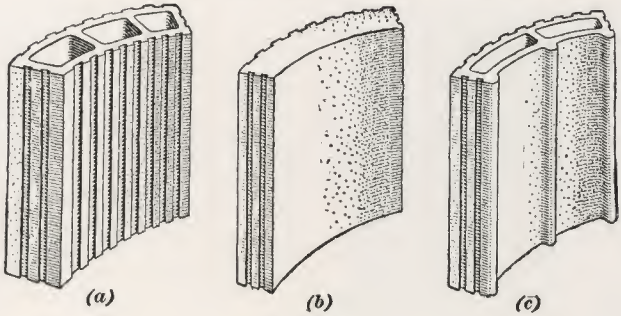


FIG. 23

from corrosion but it adds still further protection from fire in case the tile and the plaster are torn away by falling parts of the building.

The types of enclosures here illustrated are intended to show the principles of fireproofing columns that should be followed rather than the exact method of encasing them. For instance, a square column may be enclosed in a circular form of casing or a square enclosure may have either square rounded corners.

Some of the shapes of tile generally used for enclosing columns are shown in Figs. 22 and 23. Those illustrated in Fig. 22 are designed for square or rectangular coverings and those in Fig. 23 for circular coverings.

61. Plate-and-Angle Columns.—In Fig. 24 is shown a plan and in Fig. 25 a view of what is known as a plate-and-angle column which has a square enclosure of fireproofing formed of tiles *a*. These tiles are of the shape shown in Fig. 22 (*b*) and the space within the enclosure is filled with concrete. In Fig. 25 is shown the manner in which the tiles are placed to secure broken joints and proper bonding of the tiles, and this method applies to all succeeding enclosures that are illustrated only in plan, as in Figs. 26, 27, 28, 29, and 30.

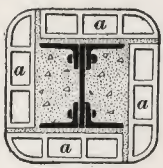


FIG. 24

62. H Columns.—The **H** column, which is made by the Bethlehem Steel Co., is shown in plan in Fig. 26. This column has a circular enclosure of tiles *a*, which are of the shape shown in Fig. 23 (*a*). In this illustration, plain hollow-tile blocks are placed in the concrete filling around the column to help fill this space, which makes the filling lighter in weight than it would be if of solid concrete.

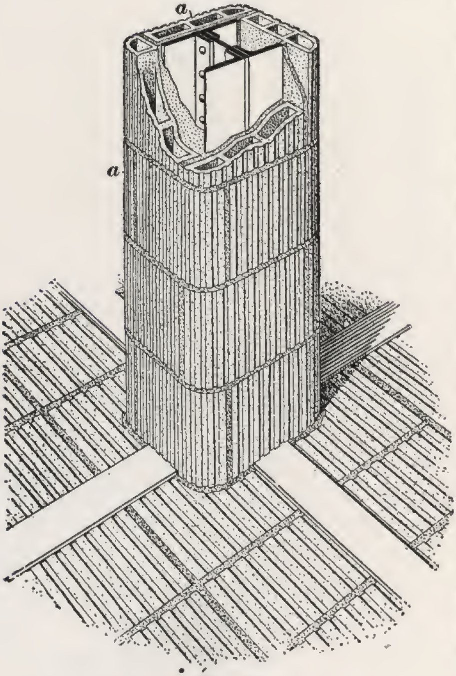


Fig. 25

63. Box Columns.—In Fig. 27 is shown a steel column, commonly known as a *box column*, which is formed of two channels and two plates. The tiles which enclose this column are of the shape shown in Fig. 22 (*a*), the single-cell tile being a portion cut from one of the same kind of tile as in (*a*).

64. Heavy Box Column.—A heavy box column is shown in Fig. 28. This column is enclosed with tiles of various shapes and thicknesses. Adjoining the column a pipe space is formed by the use of tiles. Three sides *a* of the column are protected by tiles 3 inches thick, while the side *b*, that is protected by means of the pipe space, has a covering of tile only 2 inches thick. These 2-inch tiles are used to form the walls of the pipe space, also to economize in filling in the concrete against two sides of the column.

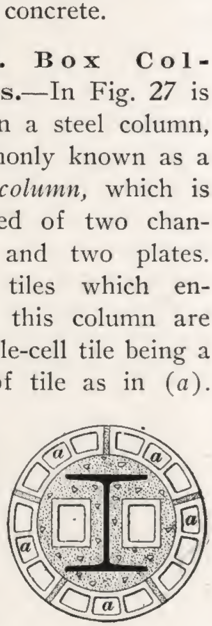


Fig. 26

The tiles used for this column enclosure are of the shapes shown in Fig. 22 (a) and (b), the form shown in (a) being made either 2 or 3 inches in thickness. The tile shown in (c) is used for the corner members of the pipe-chase enclosure. The tiles with the smaller number of cell units shown in Fig. 28 are formed of regular tiles cut to the size required.

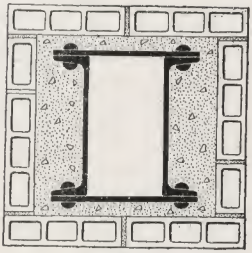


Fig. 27

65. Pipe Spaces or Chases.—If it is desired to conceal the pipes that are to be carried up beside a column, a separate pipe space or chase should be provided for this purpose, as shown in Fig. 28, rather than to attempt to conceal these pipes within the fireproofing of the column. The column itself should be entirely enclosed in hollow tile independent of the pipe chase so that any opening of the walls of the pipe chase, which may become necessary in repairing the pipes, will not expose the column.

66. Cast-Iron Columns.—The method of fireproofing a round cast-iron column by means of hollow tile is shown in Fig. 29. No concrete need be used in this method, as cast iron does not corrode as readily as steel, and consequently does not need to be coated with the cement.

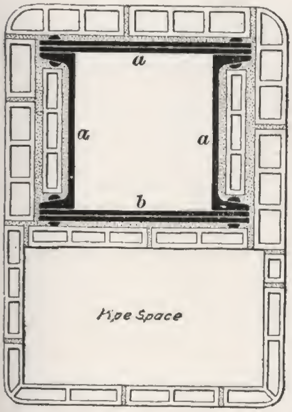


Fig. 28

Square cast-iron columns are not illustrated, but they are treated and covered in a manner similar to the round columns, using the plain regular-shaped tiles shown in Fig. 22 for the purpose.

Solid tile fireproofing blocks, as shown in Fig. 30, are sometimes used for column protection but are less effective than the hollow forms of tile. Hollow blocks are better than solid blocks, although when sufficiently thick the solid blocks are quite as effective for fire-

proofing purposes. The tiles shown in Fig. 23 (*b*) and (*c*) are applied directly against the iron column. The ribs on the inside face of the tile shown in (*c*) are designed to form an air space between the column and the inside shell of the tile.

67. A Fireproof Steel Structure.—Fig. 31 shows the portion of the steel structure previously shown in Figs. 2 and 15, after the fireproofing of the steel work has been completed and the exterior walls have been built. The fireproof enclosure for the lower part of the inside channels which form a part of the exterior wall girders is shown at *a*. The enclosure for the lower part of the interior girders is shown at *b*, the floor arches at *c*, the exterior wall columns at *d*, and the interior columns at *e*. At *f* are shown the wooden timbers called *sleepers*, which are secured to the spot grounds *g* to receive the wooden floor which is to be laid after the plastering has been completed.

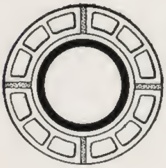


FIG. 29

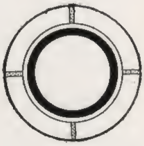


FIG. 30

TILE PARTITIONS

68. Wall tiles, especially designed to support loads, are used for building walls that are to sustain loads, such as floors and roofs, and are described in the Section entitled *Hollow Tile*. **Partition tiles** are not designed to sustain any weight other than that of the partition itself.

69. Construction of Tile Partitions.—A tile partition is built directly upon the fireproof floor arches or upon the steel beams, and is generally only one story in height. The tiles are laid in cement mortar and the partition is wedged against the floor arches or beams at the ceiling.

The tiles used for partitions are semiporous tile and are made in the sizes shown in Fig. 32.

It is neither practical nor economical to use the 2-inch tile blocks for partitions except in closets or small shafts where

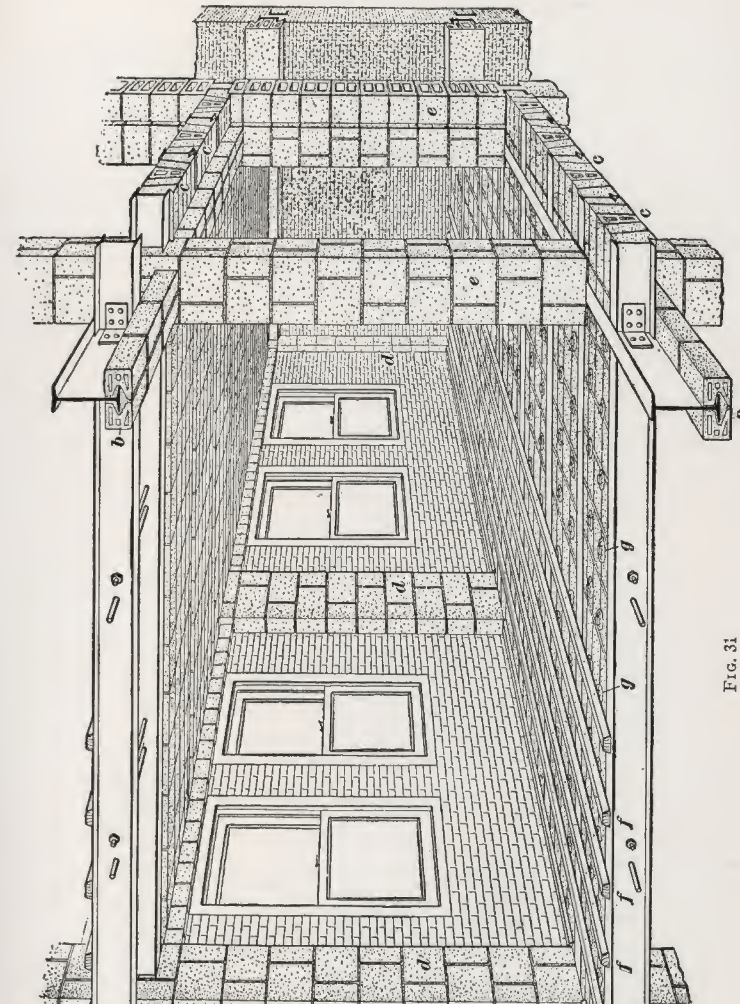


FIG. 31

the lengths and heights of the partitions are short. If they are used for long runs or high ceilings, however, they should be

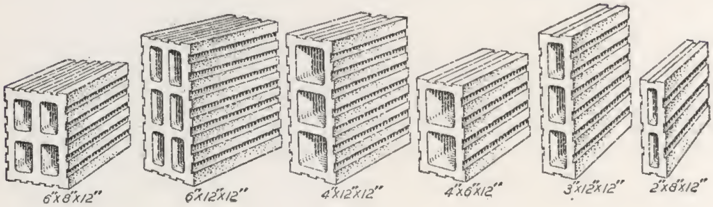
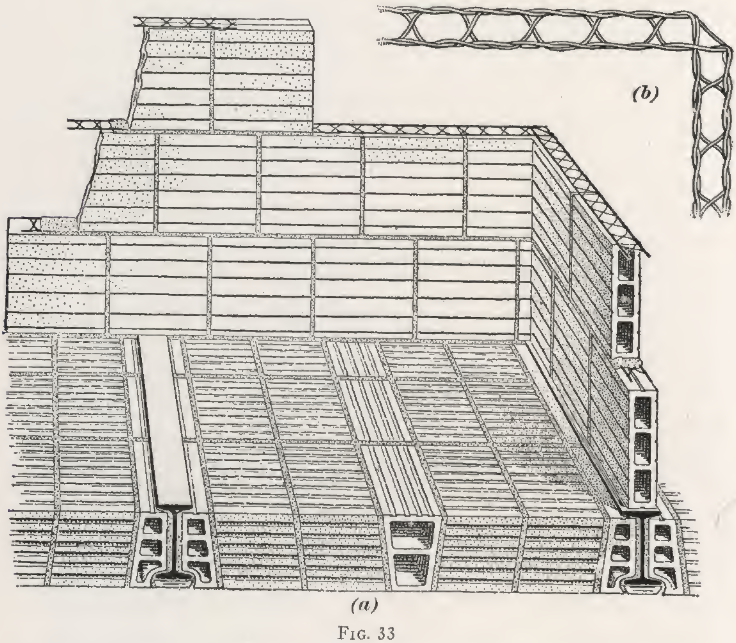


FIG. 32

reinforced with angle irons or wire truss between the courses, as shown in Fig. 33 (*a*). In (*b*) is shown a detail of this reinforcement and the manner in which a bend is made for the angle of the wall. Trusses of this character are not required for any tile partition 3 inches or more in thickness unless



(*a*)

FIG. 33

it is very high or is required to withstand a pressure of some kind. Safe practice is to allow a height of 12 feet for 3-inch

partitions, 16 feet for 4-inch partitions, 20 feet for 6-inch partitions, but the actual requirements of the building codes in cities should always be complied with, regardless of this schedule.

The weight of this semiporous tile in the various thicknesses is shown in Table IX. This is the net weight of the partition

TABLE IX

WEIGHTS OF HOLLOW-TILE PARTITIONS

Thickness of Partition Inches	Weight per Square Foot Pounds
2	10 to 14
3	12 to 16
4	13 to 19
5	20 to 22
6	22 to 23
8	28 to 33

without mortar or plaster, and these amounts should be increased from 6 to 8 pounds per square foot for each plastered surface.

TILE ROOF CONSTRUCTION

70. Book Tile.—Special blocks, known as **book tiles,** shown in Fig. 34, are often used in the construction of pitched roofs. If the roof is to be covered with concrete, tar and felt, or a similar composition, the hard, dense grade of tile may be used. If the covering is to be of slate, the porous grade of book tile should be used, as nails can be driven into it to secure the roof covering in place.

Book tiles are supported by means of **T** irons which are connected to the structural beams of the roof and are laid as shown in Fig. 35. The **T** irons are shown at *a* and the tiles at *b*.

There are two types of book tiles. The one shown in Fig. 34 (*a*) has plain ends *a* and is used for roofs, as just described. This type of tile is known as a *roof tile*. The one

shown in (*b*) has recessed ends at *a*. This type of tile is grooved, and is known as a *ceiling tile*. The grooves are for

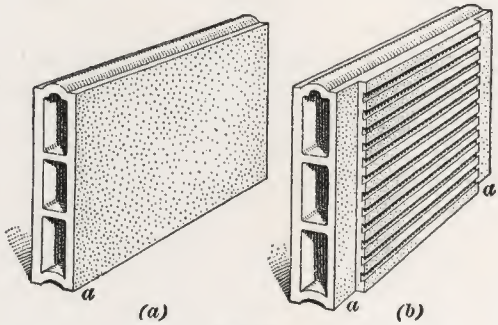


Fig. 34

the purpose of affording a key to the plastering. The recessed ends allow the bottoms of the tile and the **T**'s to be set flush so that the plaster of the ceiling will cover the **T**'s.

Book tiles are set in place and all joints well filled with cement mortar. They should not be used where heavy loads are to be placed upon the roof. These tiles do not afford pro-

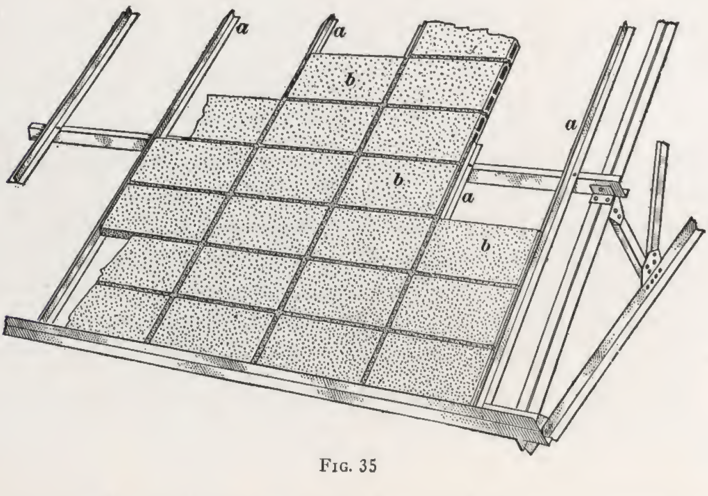


Fig. 35

tection to the steel that supports them and have no fireproofing value. They are, however, incombustible.

71. The sizes and weights of standard book tiles are given in Table X.

TABLE X

SIZES AND WEIGHTS OF BOOK TILES

Roof Tiles		Ceiling Tiles	
Size Inches	Weight Pounds per Square Foot	Size Inches	Weight Pounds per Square Foot
3×12×18	20	3×12×16	20
3×12×20	20	3×12×18	20
3×12×24	20	3×12×20	20
4×12×24	24	3×12×24	20

Government roofing tiles are $\frac{1}{2}$ inch shorter than standard book tiles and $\frac{1}{2}$ inch thinner and are made solid.

72. Flat Roofs.—Flat roofs of hollow tile for fireproof buildings are constructed in much the same way as the floors, except that the beams and girders are often set to give a slight pitch to the roof so that the water will be drained to the conductors. The tiles are so set that the top of the arch will fit closely under the top flange of the roof beams, as shown in

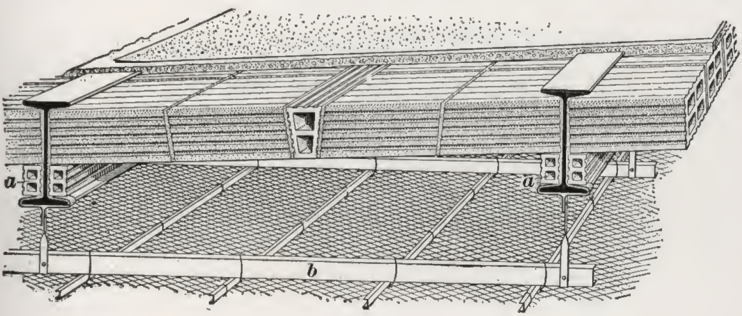


Fig. 36

Figs. 36 and 37. The roof has less of a load to support than the floors, consequently the arches are shallow and the tiles are generally too small to enclose the beams and girders entirely.

In the construction shown in Fig. 36 the webs of the beams are protected by tiles of the form shown at *a, a,* which also form bearings for the roof tiles. The bottom flanges of the roof beams are protected by the wire lath and plaster ceiling *b,* but this ceiling, which is level, may be some distance below some of the roof beams, consequently this protection is hardly

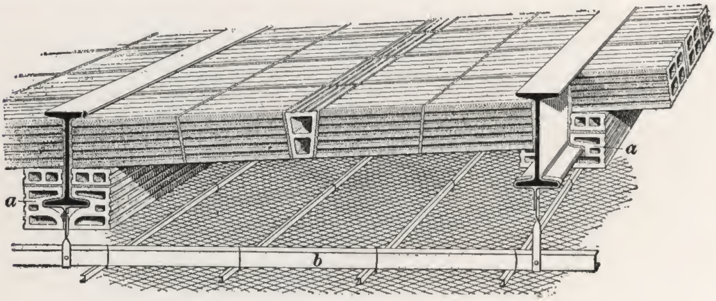


FIG. 37

sufficient. The form of fireproofing shown in Fig. 37 at *a, a* should be used if full protection is desired and the hangers for the ceiling placed on the beams before they are enclosed with the fireproofing. When it is desired to form a level ceiling, metal lath and plaster are used and the ceiling is suspended from the roof beams as shown in Figs. 36 and 37.

FIREPROOFING WITH CONCRETE

73. General.—Though structures formed entirely of concrete are in themselves fireproof, they will not be considered here. The construction of concrete floor slabs and the use of concrete in fireproofing columns, beams, and girders are, however, subjects that properly come under the head of fireproofing and will be discussed in the following articles.

It is assumed that the frame of the building, including the columns, girders, and beams, has been designed to carry safely all the floor loads and the fireproofing. The subjects to be discussed are the fireproofing of these columns, girders, and beams, the construction of the concrete floor slabs, and the nature of the materials of which the concrete is made.

The fireproofing of the girders and beams with concrete is, as in the case of terra-cotta fireproofing, so intimately connected with the construction of the floors that these subjects are best considered together. In fact, in many cases of concrete-slab floor construction, the operations of forming the slab and covering the beams and girders are done together, the forms being built for the entire construction and the reinforcement being put in place completely before concrete is poured.

74. Reinforcement of Concrete.—Concrete in itself possesses little tensile strength, but considerable compressive strength. Steel, on the other hand, possesses great tensile strength. When properly used together, these materials form a most valuable building material, the steel supplying the strength which the concrete lacks.

This strength is necessary in the beams, girders, and floor slabs which constitute the floor construction, and the application of this reinforcement to different forms of floor slabs will be shown and described. There are many forms of reinforcement and concrete floor construction that are not shown; but those described illustrate different typical forms of construction.

75. Concrete.—Concrete is not so good a heat retardant as dense or porous tile, but it is a splendid fireproofing as well as structural material when properly mixed and applied. The concrete used for fireproofing purposes may have a coarse aggregate of cinders, gravel, or broken stone of small size, and is known accordingly as **cinder concrete, gravel concrete,** or **stone concrete.** If the concrete is to be used to form floor slabs or arches, the gravel or stone aggregate should be used with the cement and sand and this mixture reinforced with steel, as may be required to carry the loads that will rest on the floor.

76. Cinder Concrete.—Cinder concrete, on account of the porous nature and the high resistance of the cinders to destruction by heat, is perhaps the best of all concretes for fireproofing, but as it possesses comparatively little strength,

it is not suitable for structural purposes. Blast furnace slag is often used for the coarse aggregate in concrete as it provides more strength than cinders and has also a high resistance to heat.

Cinders selected for concrete should be free from particles of unburned coal and, where possible, should be ground to a suitable and uniform size. The cinders should be thoroughly mixed with the cement, sand, and water to insure that they are completely covered with this mixture and that all voids in the cinders are filled, to prevent rusting or corrosion of the steel such as often occurs when cinder concrete is used. A wash of cement, sand, and water is sometimes applied to steel work that is to be encased in cinder concrete, and allowed to become dry before the concrete is deposited, to prevent contact with the cinders in the concrete.

Steel columns that are to be encased are sometimes given a coating of cement and sand mortar that is applied with a trowel. This is done to protect the column against corrosion as well as fire.

Cinder concrete is usually made of one part Portland cement, two parts of sand, and five to seven parts of cinders. The materials should be thoroughly mixed together before and after the water has been added and when the concrete is deposited it should be thoroughly tamped so that it will entirely fill the spaces and form a compact mass.

Cinder concrete is used as a filling around columns that are enclosed by tile fireproofing, as shown in Figs. 25, 26, and 27, and also as a filling between wooden sleepers that are placed on fireproof floor arches to receive a wooden floor, as shown in the illustrations of floor construction.

77. Stone and Gravel Concrete.—Gravel concrete or concrete having a coarse aggregate of broken stone is much stronger than cinder concrete, but is more likely to be injured by the extreme heat of a burning building, as the heated surface expands while the remaining parts remain comparatively cool, thus causing unequal expansion that will cause cracking or warping much the same as in brickwork. Extreme heat is

also apt to disintegrate the gravel and stones. For this reason all steel reinforcement in concrete should be located at least $1\frac{1}{2}$ inches from the exposed surface for columns and beams and $\frac{3}{4}$ inch for floor slabs. Water thrown with force upon the surface of heated concrete by means of a hose is liable to tear away this protecting surface and expose the steel directly to the flames.

78. Forms of Reinforcement.—The forms of steel reinforcement may be classified as single loose rods, or bars, fabrics formed by welding or weaving bars or wires together, sheet metal that has been cut and expanded to form a mesh, sheet metal that has portions expanded to form a mesh and other portions formed into ribs, and sheet metal that has been formed into a series of grooves.

Since it is the difference in the form of the reinforcing material that constitutes the different systems, the description of these reinforcing materials will be given in connection with their application to the various floor constructions in which they are employed.

The term bar and rod are used interchangeably in the description of reinforcement for concrete and may apply to round or square forms and plain or deformed shapes.

CONCRETE FLOOR CONSTRUCTION

79. Floors With Loose Steel-Bar Reinforcement. Bars for reinforcement may be square, round, or oval in section, and either plain, twisted, or deformed. A twisted square bar is shown in the top illustration of Fig. 38 and examples of deformed bars having projections of different shapes are shown in the two lower ones. The object of twisting and deforming the bars is to cause a better adhesion between the steel and the concrete, as the projections and irregularities of the bars prevent the steel from slipping through the hardened concrete when under severe stress. These deformed bars are, however, more expensive than plain ones and in the majority of cases plain bars are used for reinforcing concrete.

80. Bars for reinforcement are usually from $\frac{1}{2}$ inch to $\frac{3}{4}$ inch in diameter and for flat slab construction a large number of small bars is commonly used instead of a small number of large bars. By this arrangement the steel presents a larger surface to which the concrete may adhere, and also the tensile strength is distributed more evenly throughout the mass of concrete.

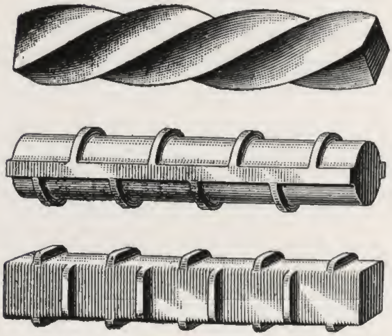


Fig. 38

81. Loose steel bars for reinforcing concrete floor slabs may be placed over the tops of the beams as shown in Fig. 39, between the beams as in Fig. 40, or at the bottoms of the beams as in Fig. 41.

In Fig. 39, the rods *a* are the ones that support the slab, and the rods *b* are provided to counteract the effects of contraction and expansion. These rods are wired together where they cross. The rods *a* are supported on the tops of the beams and are bent down so as to be near the bottom of the slab where

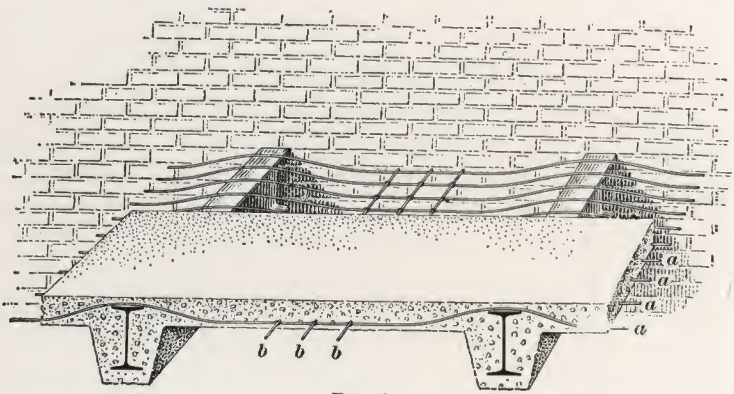


Fig. 39

they will be the most effective. The top of the slab is designed to be an inch or two above the tops of the beams so as to cover

the rods. The rods in Fig. 40 are cut in between the beams and placed so that they will be near the bottom of the slab.

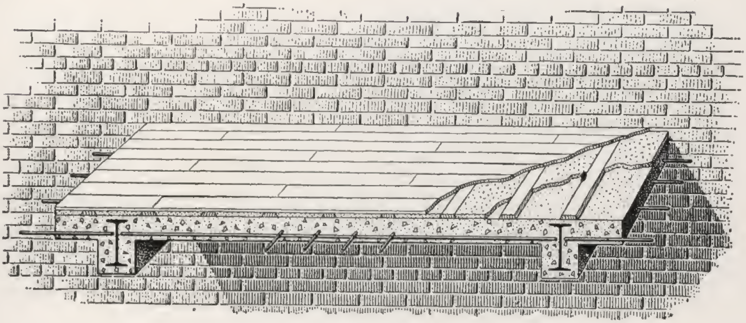


Fig. 40

Expansion rods similar to those shown in the previous figure are shown in this example.

An example of reinforcement at the bottoms of the beams is shown in Fig. 41. The ends of the rods may rest on the bottom flanges of the beams or may be turned up as shown in the figure. Cinder concrete or plain cinders are used to fill the space above the slab. This filling is brought up to the level of the tops of the beams so that the floor sleepers can rest upon it.

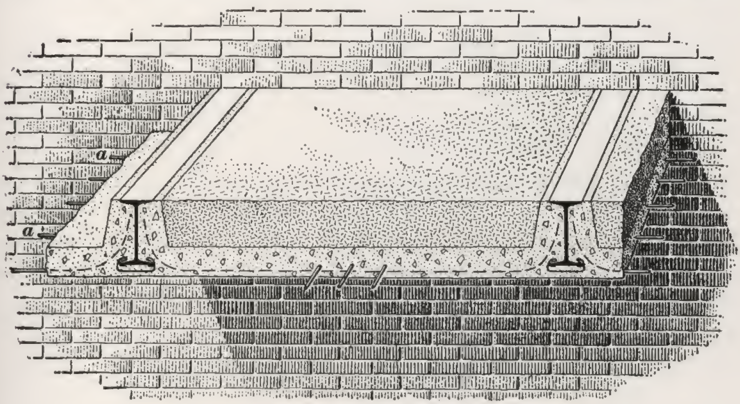


Fig. 41

Wire mesh is sometimes wrapped around the bottom flanges of the beams to afford a good grip for the concrete beneath the

beams. The object of making a slab of this description is that plaster may be applied directly to the surface and a flat ceiling obtained. With the other slabs shown it will be necessary to hang a ceiling if a flat ceiling is required. In plastering on a concrete surface such as the under surface of the slab in Fig. 41, a patent plaster should be used that is guaranteed to adhere to the cement.

82. Another example of the arrangement of reinforcement at the bottoms of the beams is shown in Fig. 42. The reinforcing bars *a* have bearings on the bottom flanges of the steel beams, as shown at *b*. Sheet-metal forms *c* are used and

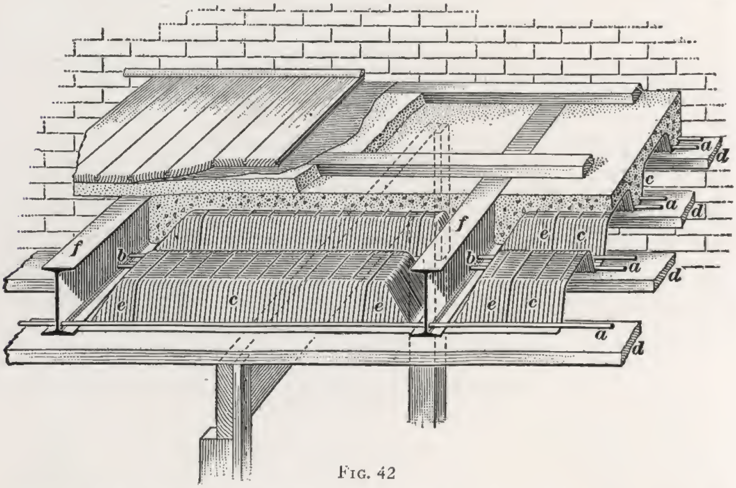


Fig. 42

rest on the wooden centering boards *d*. When the concrete is poured, the concrete beams and slabs are formed at the one operation. These metal forms have special closed end members as shown at *e*, which permit of the sides of the steel beams being covered with concrete as shown. After the concrete has become hard, the centering and steel forms are removed and the ceiling that is exposed consists of concrete beams and slabs. There are several modifications of this form of construction but they are similar in principle.

If the bottoms of the beams *f* are to be protected, they must be enclosed in metal lath before the wooden centering is

erected. After the floor construction has been completed and the centering removed, this metal lath must be coated with a cement mortar.

83. Floors With Welded or Woven Reinforcement.—In reinforced-concrete work, the principal reinforcing bars extend from one bearing or support to another and cross-bars are run at an angle to the main bars. The placing of these bars and cross-bars in the construction requires considerable time and they are liable to be displaced when the concrete is poured. As a remedy for this condition a form of reinforcement has been placed on the market in which the main reinforcing bars are rigidly connected with the cross-bars. These forms of reinforcement are sometimes called *fabrics,* and are made in different ways, as shown in Fig. 43. In (*a*) the bars are welded together by electricity; in (*b*) the cross-bars are formed of a lighter wire that is twisted around the principal bars. In (*c*) the principal bars consist of several strands of wire and the cross-wires are wound around them. In *b* and *c* the cross-bars run diagonally.

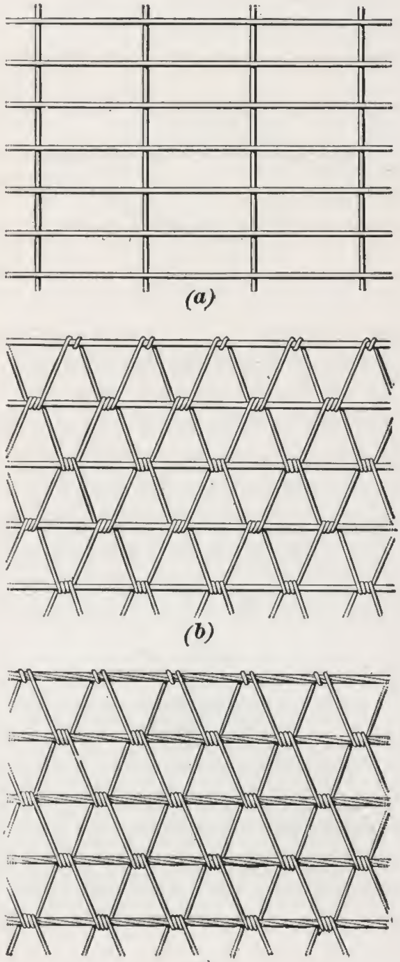


Fig. 43

84. To fulfil the requirements of a reinforcing material, these fabrics should have a large number of small strands rather than a small number of large ones. There is on the other hand greater danger attending the use of small strands on account of corrosion of the material and the greater difficulty of keeping the light reinforcing material from becoming displaced when pouring the concrete.

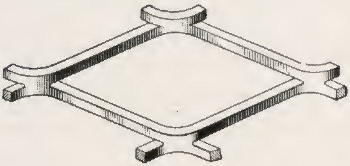


Fig. 44

85. Expanded - Metal Reinforcement. — Another widely used form of reinforcement is known as *expanded metal.* There are several types of this kind of reinforcement. One type consists of a heavy-gauge metal which is expanded to form large openings, or meshes, as shown in Fig. 44, and, on account of this open character, requires wooden centering on which the expanded metal may be placed and the concrete poured. The other type, shown in Fig. 45, is formed of a lighter-gauge sheet metal. The mesh is of a smaller size and ribs are formed at intervals to provide the strength that is necessary to carry the loads

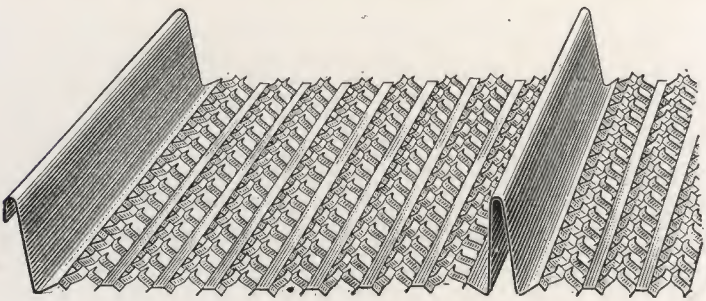


Fig. 45

between the bearing surfaces. On account of the small mesh of this form of reinforcement only enough concrete can pass through to form a clinch with the metal, and the ribs stiffen the sheets so that they are self-sustaining for spans not exceeding 5 feet. The advantage of this kind of reinforcement is that for

these short spans no support or centering is required. For spans of 6 to 8 feet, a temporary brace or support under the middle is all that is required.

The one objection to this form of reinforcement is that the metal is not embedded in the concrete slab and must be protected by means of a coating of cement mortar applied after the concrete is set.

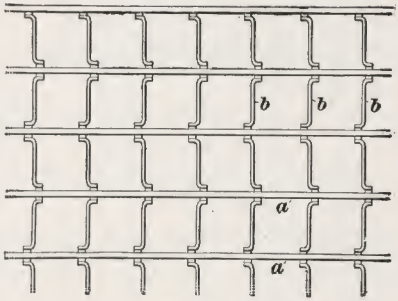


Fig. 46

86. A form of reinforcement made of expanded metal is shown in Fig. 46. This material has the main ribs *a* heavier than the cross-ribs *b*. The main ribs provide the strength necessary for the reinforcement, while the cross-ribs act as spacing bars and also as shrinkage bars when the reinforcement is embedded in the concrete.

87. Arched Floor Construction.—The kinds of reinforcement shown in Fig. 43 may be used in the formation of

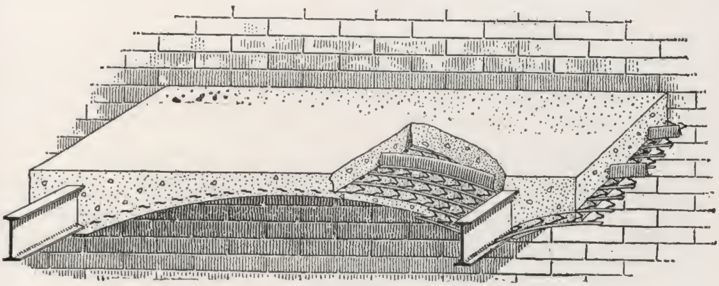


Fig. 47

what are known as concrete arches, such as that shown in Fig. 47. For this purpose, however, the heavy-gauge fabrics and those having ribs such as shown in Fig. 45 are usually formed at the mill into the shape of arch desired, and are set in between the beams.

88. Floors on Self-Centering Sheet Metal.—In Fig. 48 is shown a form of sheet-metal centering for floors. It is placed directly on the tops of the steel beams. The concrete *a*

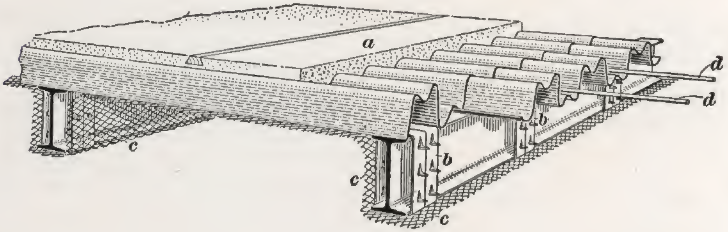


FIG. 48

is poured into the channels on the upper side of the centering and to a level of about 1 inch above the top of the centering. The centering is not covered with concrete on the under side, hence the metal is exposed to the action of fire. If a plastered ceiling is desired it must be formed by attaching metal lath to the under surface of the centering and around the beams. At *b* are shown devices designed to hold in place the metal lath *c* that is wrapped around the steel beams. This ceiling affords some protection for the under surface of the sheet metal and the steel beams but the construction cannot be considered as absolutely fireproof.

The device shown in Fig. 49 is sometimes used to attach the ceiling lath to the sheet-metal centering. It consists of small pointed pieces of sheet iron such as shown at *a*. They are placed between two adjacent sheets of metal centering and project downwards as shown at *b*. The points *b* project through the lath and are bent up around the strands of the lath, thus securing it in place.

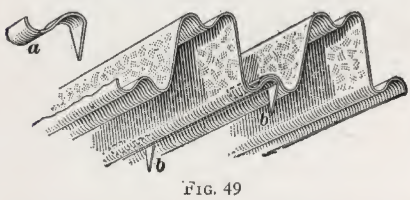


FIG. 49

When especially heavy floor loads are to be sustained with the kind of reinforcement described, reinforcing bars should be placed in each of the forms as shown in Fig. 48 at *d*.

89. The form of centering shown in Fig. 50 (*a*) consists of a sheet of metal bent so as to form a series of dovetailed grooves on both sides of the sheet as shown at *a*. The concrete of the floor slab fills the upper grooves and forms a sort of key which holds it firmly to the metal. Plastering will adhere to

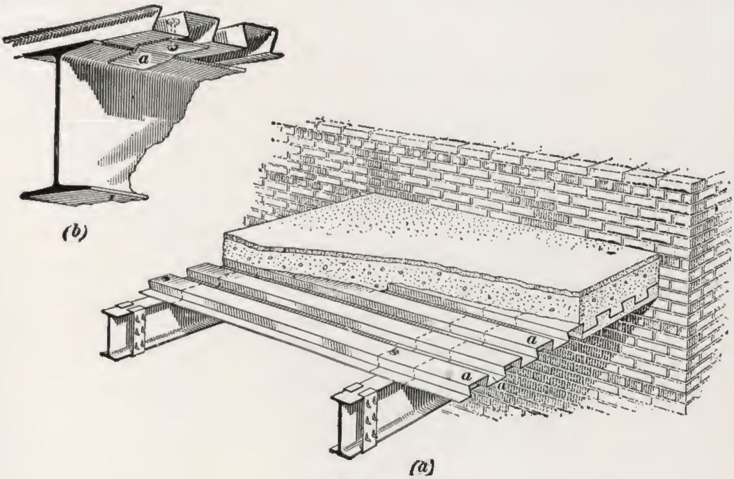


FIG. 50

the under side of the sheet, as the grooves are of a dovetailed shape. When plastering is applied the metal is protected from fire, otherwise the under side of the steel will be exposed to the flames. The method of securing this form of centering to the beams is illustrated at *a* in (*b*).

FIREPROOFING BEAMS AND GIRDERS WITH CONCRETE

90. Concrete fireproofing of steel beams and girders is generally installed at the same time as the concrete floor slabs. When properly applied, the concrete not only affords protection from fire but protects the beams from corrosion. For complete fire protection, the webs and flanges of the beams and girders must be encased in concrete. If the concrete is of sufficient thickness, that is, not less than 2 inches thick, it will hold securely around the lower flange of beams without

the aid of steel reinforcement. Nevertheless it is good practice and gives greater security from failure during a fire, to encase the lower flanges of all beams in metal fabric or expanded metal to afford a key for the concrete. In Fig. 51 is shown a steel beam with the lower flange wrapped in a metal fabric. This fabric extends across the bottom of the beam, as at *a*, and

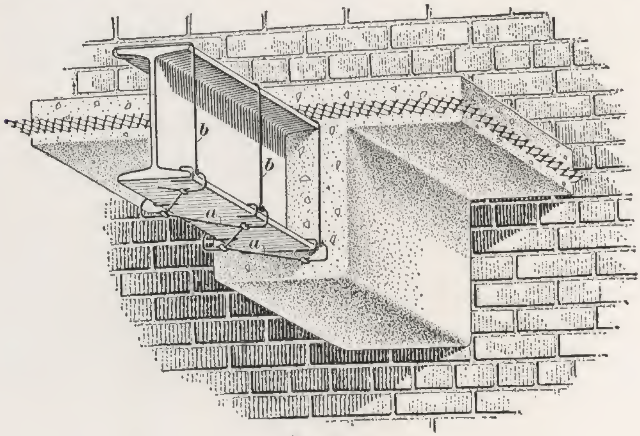


FIG. 51

extends vertically from flange to flange, as at *b*, leaving the space between the reinforcement and the web of the beam to be filled with concrete. Care should be taken in using reinforcement for the concrete on the under side of the beam, to keep it $\frac{3}{4}$ inch to 1 inch away from the flange so that the concrete may surround the reinforcement and obtain a firm hold on it.

FIREPROOFING COLUMNS WITH CONCRETE

91. Where concrete is applied for the purpose of fireproofing only and where its strength is not essential, it is best made with cinders, as cinder concrete is not only one of the best fire-resisting substances but is the lightest form of concrete.

92. In some cases forms are set up around the columns, forming a space of 2 or 3 inches outside them. These forms may be circular, square, or rectangular in shape, as may be convenient. The concrete is then poured into the forms,

entirely burying the steel columns. The forms are removed and the concrete is generally finished with a plaster finish.

93. Another method is to form a square or circular enclosure of metal furring and lath around the column. Concrete is poured into the space between the lathing and the column. Fig. 52 illustrates a square enclosure, the concrete filling being shown at *a*. The concrete *b* that projects through the metal lath in this construction affords an excellent key for the finishing coat of wall plaster. The concrete should be made wet enough to run into all corners and angles so as thoroughly

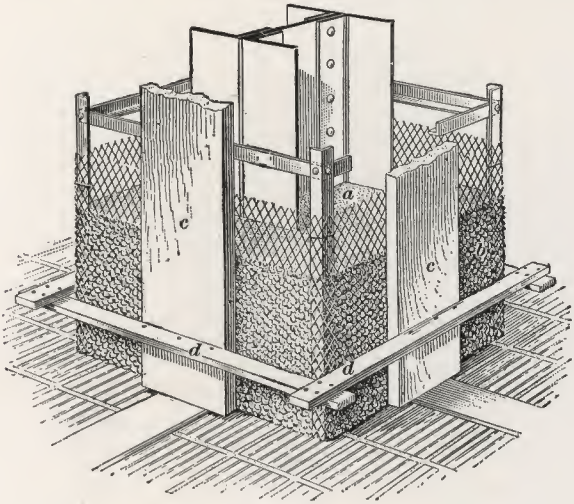


Fig. 52

to bury the steel work. The upright planks *c* are placed against the lath to keep it from bulging outwards when the concrete is poured. These planks are held in place by the braces *d*.

94. Use of the Cement Gun.—A method of fireproofing that is very successful and which requires no forms is to apply cement mortar to the surfaces of the steel by means of a *cement gun,* which is an apparatus that shoots thin cement mortar in a stream against the columns, beams, etc., and

causes it to penetrate all cracks and cavities. Columns have been coated with $1\frac{1}{2}$ inches of cement mortar by this means and thus successfully protected from injury by fire as well as corrosion. Cement is applied in that way by companies that make a specialty of that kind of work and own their own implements.

FIREPROOFING WITH BRICK

95. Experience shows that brick is probably as good a material as can be found from the fireproofing standpoint, and that it will withstand the heat from an intense fire for a long time without failing.

96. Brick Floor Arches.—Brick arches are not used to any great extent now in fireproofing on account of their weight and expensiveness. The brick arch is perhaps the strongest type of arch for the span it occupies, with the possible exception of the concrete arch. Owing to its weight, the brick arch requires the strongest and heaviest framework and is therefore the most expensive construction.

The brick used in floor arches should be hard and well burned and the joints filled with strong cement grout. The bricks in one row should break joints with those in the rows adjoining, and in case the arch is a double rowlock arch the joints of the upper rowlock should break joints with those of the lower rowlock. The most favorable span for a brick arch is between 4 and 6 feet and the rise should be about $\frac{1}{8}$ of the span, or $1\frac{1}{2}$ inches to the foot. Arches of over 6 feet span should be formed of two rowlocks. To protect the lower flange of the I beams, brick arches should be sprung from heavy terra-cotta skewbacks with lips meeting at the center of the flange.

97. Brick Enclosures for Steel Columns.—The steel wall girders and columns in exterior walls are generally enclosed with brick. In structures having floor arches of brick, the interior steel columns are frequently enclosed by a 4-inch brick wall instead of with terra cotta.

These brick enclosures for columns form a very effective protection, and the concrete filling, previously described under Fireproofing Steel and Iron Columns With Terra Cotta, is then omitted.

FIREPROOFING WITH METAL LATH AND PLASTER

98. Protecting Beams and Girders.—Metal furring, lathing, and plaster are used as a protection for beams, girders, columns, etc. There is a difference, however, between pro-

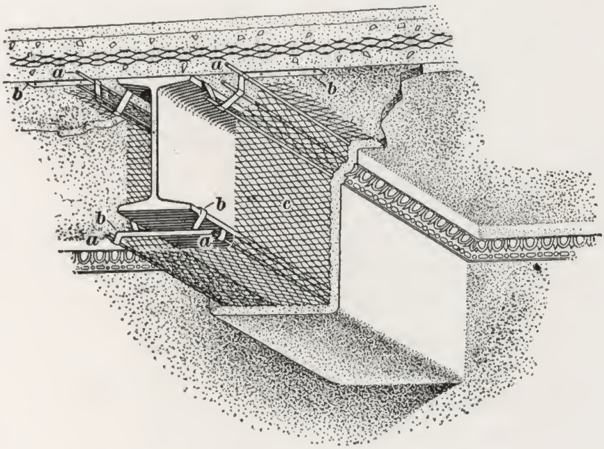


FIG. 53

tecting steel work and fireproofing it, which it will be well to keep in mind. A *protected* beam encased in wire lathing and plastering is not protected from corrosion and the plaster work with which it may be encased is not likely to survive a very hot or prolonged fire. A *fireproofed* beam is protected from both corrosion and fire.

A protected beam is shown in Fig. 53. Steel furring bars *a* are secured at intervals to the straps *b,* and these are fastened to the steel beam and ceiling construction as shown. The metal lath *c* is stretched over the frame thus provided and the furring bars, straps, and lath are tied together by the use of steel wire.

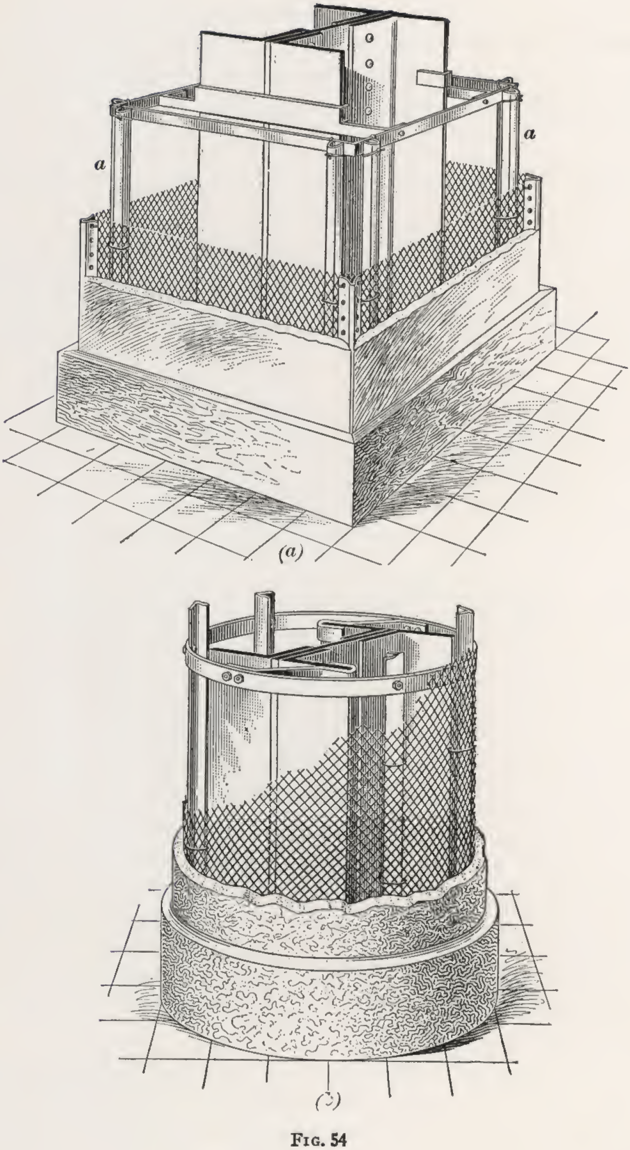


FIG. 54

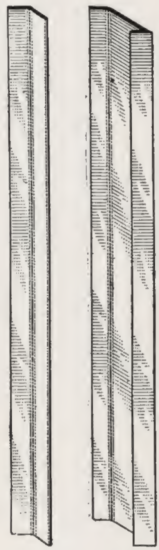
Three coats of plaster are applied to this lath and the protection is completed.

99. Protecting Steel Columns.—In Fig. 54 (*a*) is shown one method of protecting a column by means of a square enclosure of lath and plaster. The wire lath is fastened to the ribs *a*, which are secured to the column in such a way as to provide a space between the wire lath and the column. In (*b*) is shown a somewhat similar method of protecting a column by means of a cylindrical enclosure.

FIREPROOF PARTITIONS

100. Materials.—Fireproof partitions are used to divide a floor into separate rooms, halls, etc., so that fire cannot spread from room to room. They are constructed of non-combustible materials such as terra cotta and brick, or of metal lath and plaster. Partitions of terra-cotta tile have already been described, and the construction of fireproof partitions using metal lath and plaster will now be considered.

The principal material used in the construction of these partitions is steel, in the shape of studs and metal lath. This material is buried in mortar or plaster, or else is covered by them, and is thus protected from destruction by flames. It is the mortar or plaster that gives these partitions the fireproof value that they possess, while the metal studs and lathing simply hold the mortar in place.


(*a*) (*b*)
FIG. 55

101. Metal Studding. — Studding for fireproof lath and plaster partitions may be of rolled steel in the form of standard angles and channels or of sheet steel which is bent into shapes similar to rolled-steel studding. In Fig. 55 are shown the common forms of *rolled-steel studding*. In (*a*) is an angle and in (*b*) a channel, which are the principal forms employed.

In Fig. 56 are shown the standard forms of *sheet-metal studding.* That shown in (*a*) is a *channel stud;* in (*b*), an **I** *stud;* in (*c*), a **T** *stud;* in (*d*), a **U** *stud;* and in (*e*), an *angle stud.* A *channel socket strip* (*f*) is made to hold the

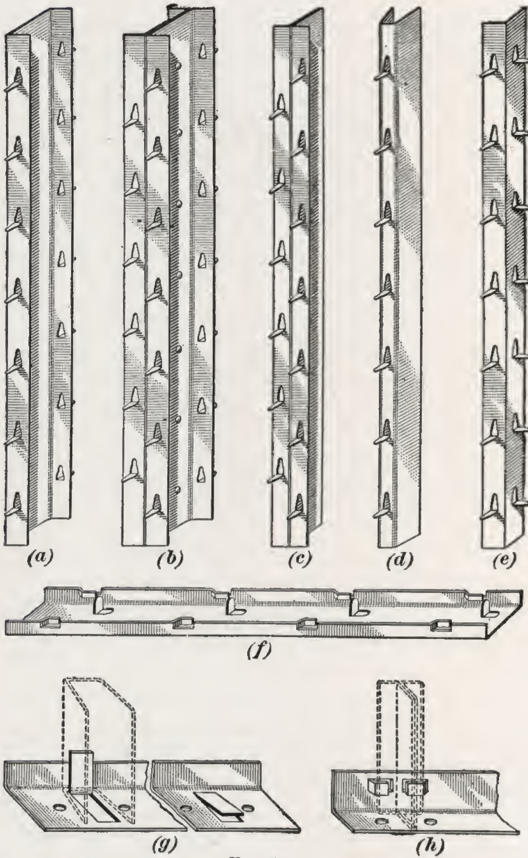


Fig. 56

channel and **I** studs at the ceiling and the floor, the socket strip being secured to the ceiling and floor by the use of expansion bolts or lagscrews. In (*g*) is shown a *socket strip* designed to receive the **U** stud; in (*h*), a *socket strip* for holding an **I** stud. These last two are in the form of angles.

There are other devices for securing the studs to the ceiling and floor, such as the one shown in Fig. 57. Brackets *a* are slipped on the ends of the **T** stud, and the brackets are secured to the ceiling and floor by means of nails.

Fig. 58 shows a rolled-steel channel stud and the manner in which the ends are treated to provide suitable connections with the ceiling and the floor construction. The connection at the top of the stud consists of an angle riveted to the stud, while at the bottom the channel is bent to a right angle to form the connection. Both of these connections have holes to receive expansion bolts or screws which may be used as a means of fastening the stud to the ceiling and the floor construction.

The simplest method of securing studding to concrete slabs is to cut shallow holes of the shape of the stud in the ceiling and floor and to spring the studs into them. The studs will then extend into the concrete for about $\frac{1}{4}$ inch on each end, and when the wire lath is secured to the studs they will be held rigidly in place

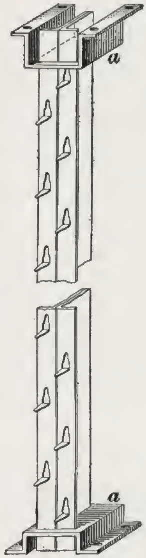


Fig. 57

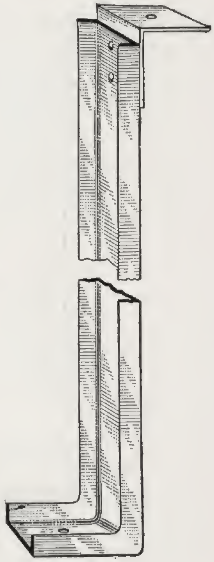


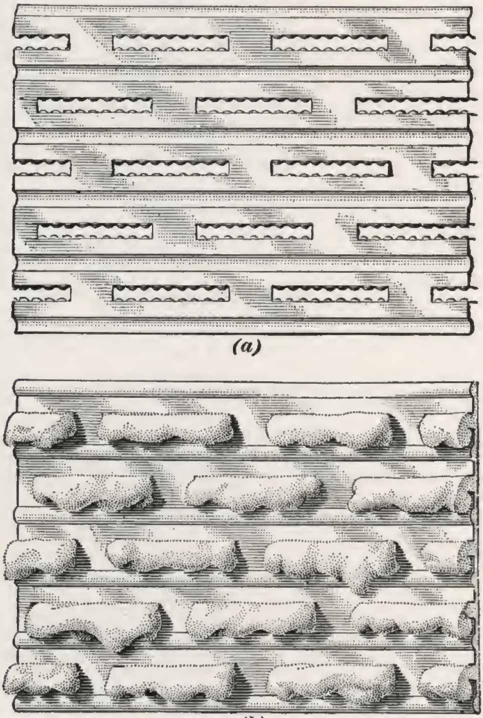
Fig. 58

102. Securing Metal Lath to the Studs.—It will be observed that the sheet-metal studding is provided with prongs which are punched out of the thin metal of which the studs are made. These prongs project and are designed to hold the metal lath in place. Sheets of metal lath are placed against the studs and the prongs project through the metal lath and are hammered flat so as to enclose one or more strands of the lath, thus holding it securely. Rolled-metal studs are not pro-

vided with prongs and the metal lath must be fastened to them with annealed wire, which is a wire that will stand considerable bending before it will break.

METAL LATH

103. Types of Lath.—Metal lath is very similar in form to some of the reinforcing metal fabrics used in floor construction, but is lighter in weight, and is used on ceilings and



(a)

(b)

FIG. 59

partitions as a groundwork or key for plastering. In fireproof partitions metal lath only should be used.

There are two principal types of metal lath, classed according to the proportion of openings in them. One type is *per-*

forated sheet-metal lath, in which the area of the openings is small in comparison with the solid surface. The other type is formed by *expanded-metal* or *woven-metal* fabric, in which the area of the openings is greater than the area of the solid part.

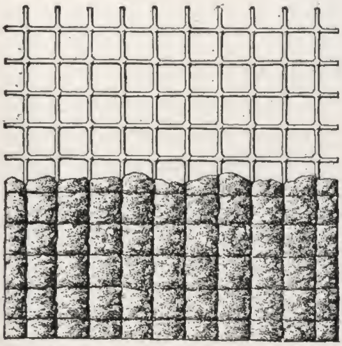


Fig. 60

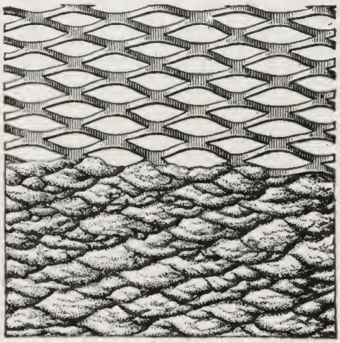


Fig. 61

A lath that has a small area of perforations, as that shown in Fig. 59 (*a*), will be only partly covered on the back surface by the plaster, as shown in (*b*), while a lath with large perforations permits more plaster to go through and cover the mesh, thus protecting the metal from fire and rust. This type is illustrated in Figs. 60 and 61. The type of lath with the large proportion

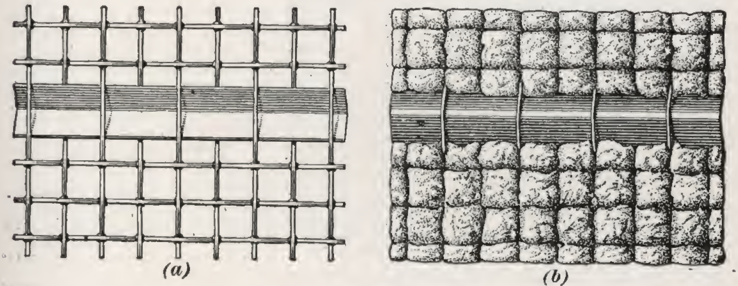


Fig. 62

of openings is made either of a woven mesh, as in the case of the Roebling wire lath, Fig. 60, or of expanded metal, Fig. 61, of which there are several different forms on the market.

104. Protecting Metal Lath.—Metal lath that is fully embedded in plaster is in little danger of corroding. It is

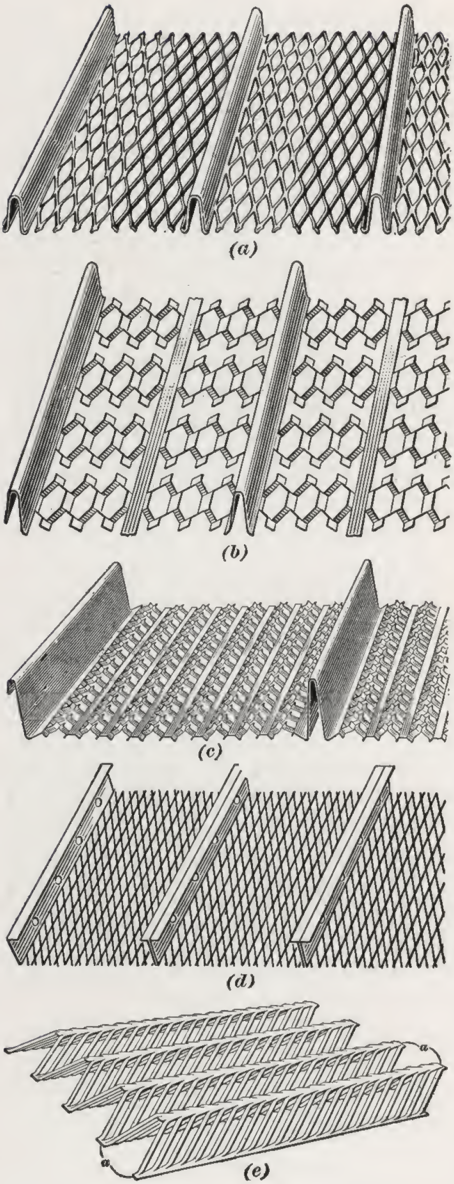


FIG. 63

nevertheless well for all metal lath to be either painted or galvanized to protect it from corroding, since it is never certain that the back of the lath will be entirely covered with plaster. Lath of the sheet-metal type, the back of which is always partly exposed to the air, must be especially well protected. This protection consists of galvanizing, or covering with a coating of zinc; of painting with oil paint; of japanning, a covering that is baked on the metal; besides other methods, all of which are designed to prevent corrosion of the metal.

105. Reinforced Metal Lath.—Metal lath is reinforced where special rigidity is required, as where the studding or furring is widely separated. The reinforcement is also used as a substitute for studding in certain cases.

Woven-metal lath is stiffened by means of **V** stiffeners, which are attached to the lath by means of clips or are woven into the fabric. Solid round bars are also sometimes used for the same purpose. The metal lath shown in Fig. 62 (*a*) shows **V**-shaped stiffeners. The **V** rib projects about $\frac{3}{8}$ inch above the back of the lath, as shown in (*b*), which is the rear view of a plastered section of the lath.

Expanded metal is reinforced by forming **V** ribs in the sheet of metal of which the lath is made, as in Fig. 63 (*a*), (*b*), and (*c*); with **T**-shaped ribs, as in (*d*), or by bending the lath as shown in (*e*). These reinforcements stiffen the lath considerably and with the assistance of a temporary wood bracing they are stiff enough in small partitions to take plastering without the use of studding.

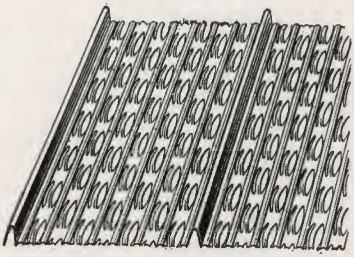


Fig. 64

Sheet-metal lath is reinforced by having **V** ribs stamped in the sheets as shown in Fig. 64.

CONSTRUCTION OF PARTITIONS

106. Solid Partitions.—Fireproof partitions are built either solid or hollow. A solid partition is built of reinforced lath or of steel studs with one layer of lath attached, and this construction is enclosed in a solid mass of plaster. The usual thickness of solid partitions is from $1\frac{3}{4}$ inches to 3 inches. The size and weight of the studding or lath are usually governed by the height of the partition as well as its length. For instance, a partition made with 2-inch studs will not be rigid if more than 12 feet in height and 15 feet in length. If the partition is larger than these dimensions it will be necessary to use larger studding. Studding placed 12 inches apart on centers makes a stiffer partition than when 16 inches on centers.

107. Solid partitions formed with rolled-steel studs, metal lath, and plaster, should be made as follows:

The studding should be of $\frac{3}{4}$-inch steel channels for a partition having a height of 10 feet or less, and of 1-inch channels

TABLE XI

CORR-MESH PARTITIONS

Height of Partition Feet	Gauge Number of Lath	Thickness of Partition Inches
Up to 8	28	$1\frac{3}{4}$
8 to 12	28	2
12 to 13	26	2
13 to 14	26	$2\frac{1}{4}$
14 to 15	26	$2\frac{1}{2}$
15 to 16	24	$2\frac{1}{2}$
16 to 17	24	$2\frac{3}{4}$
17 to 18	24	3

If over 18 feet in height, uprights of small angles, T's, or channels should be provided, and the Corr-Mesh sheets placed horizontally.

for partitions over 10 feet in height. Studding should be spaced not to exceed 16 inches on centers and be set into or securely anchored to the floor and ceiling construction.

TABLE XII

PARTITIONS REINFORCED WITH HY-RIB

Partitions		Hy-Rib	
Height Feet	Thickness Inches	Gauge Number	Reinforcement Inches
Up to 10	$1\frac{3}{4}$	28	$\frac{13}{16}$
12	2	26	$\frac{13}{16}$
		28	$\frac{15}{16}$
14	$2\frac{1}{4}$	24	$\frac{13}{16}$
		26	$\frac{15}{16}$
16	$2\frac{1}{2}$	26	$\frac{15}{16}$
18	$2\frac{3}{4}$	24	$\frac{15}{16}$
20	3	22	$\frac{15}{16}$

Metal lath should be not less than No. 27 gauge and should be securely tied to one side of the studding with No. 18 gauge annealed wire.

108. A form of metal lath called **Corr Mesh** is illustrated in Fig. 63 (*b*), and Table XI has been compiled by the manufacturers to indicate the gauge of this form of metal lath that should be used for solid partitions of various heights, also the proper thickness for the finished plastered partition.

A form of metal lath known as **Hy-Rib**, shown in Fig. 63 (*c*), is also used for solid plaster partitions. Table XII indicates the gauge of metal and thickness of partitions for various heights according to the recommendations made by the manufacturers of this lath. In the table, under the heading Reinforcement, Inches, are given the sizes of the **V** ribs in a direction perpendicular to the face of the lath.

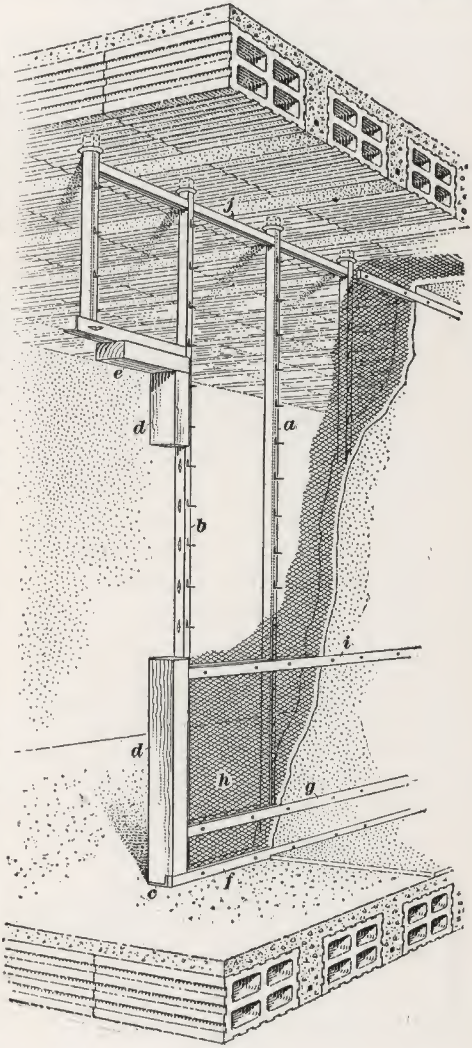


Fig. 65

109. Construction of Solid Partitions.—Examples of solid partitions, with details of their construction, are shown in

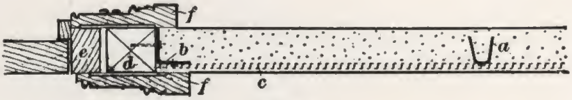


FIG. 66

the accompanying figures. In Fig. 65 the use of a sheet-metal studding with prongs is shown. At *a* is shown a **U** stud and an angle stud at *b* forms the jamb of the door. The head of the door is also an angle section. These studs are connected with the floor by means of an angle-shaped socket strip *c*, and are let into holes cut into the ceiling. Where these holes are larger than the studs the extra space is filled with cement mortar.

The metal lath is stretched over the surface of the studs and the prongs are hammered flat, enclosing one or more strands of the lath, and securely holding it in place.

Wood bucks *d* and *e* are secured to the angle studs by means of screws or bolts. The projecting prongs on the jamb side of the angle studs *b* are hammered flat so that the buck will fit close to the studs. Grounds to which the baseboards are nailed are shown at *f* and *g*. These consist of $\frac{3}{4}$-inch or $\frac{7}{8}$-inch wooden strips placed on each side of the metal lath *h* and screwed or nailed together. Similar grounds are shown at *i* and *j* to provide nailing for a chair rail and picture molding.

Fig. 66 shows a horizontal section through a portion of a solid partition such as shown in Fig. 65. The **U** stud is shown at *a*, Fig. 66, the angle stud forming the door jamb at *b*, and the metal lath at *c*. A buck *d* is screwed to the angle stud, and the door jamb *e* and the trim *f* are all nailed to the buck.

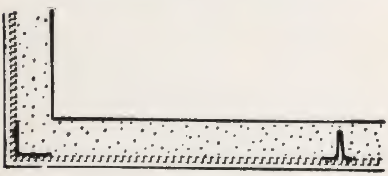


FIG. 67

Fig. 67, which is also a horizontal section, shows the use of an angle stud at the corner of a wall. The prongs occur on both sides of the angle so as to afford a strong grip on the metal lath.

110. Similar partitions can be formed by the use of rolled-steel studs, as is shown in Fig. 68. The principal difference is that no socket is used, the ends of the studs being bent over and fastened to the ceiling and floor construction. Braces are

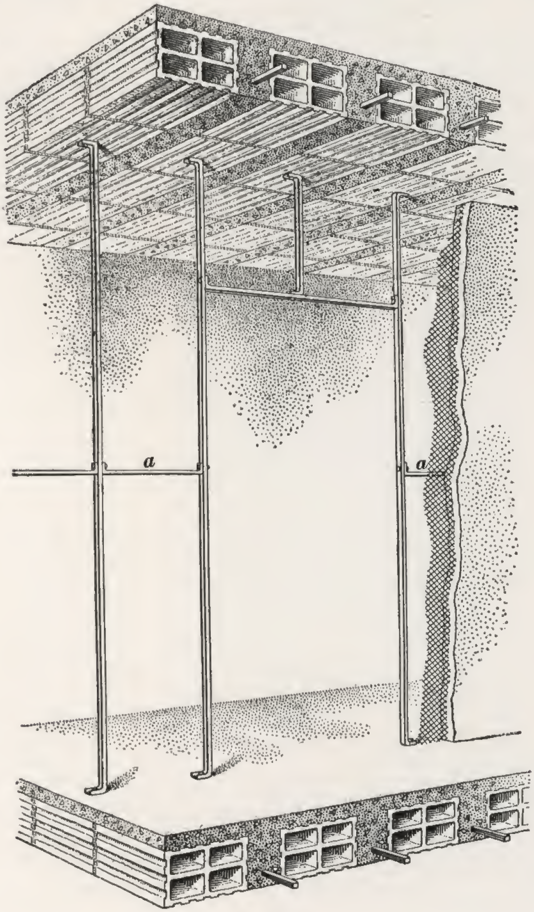


Fig. 68

shown at *a*, *a* for stiffening the studding. Grounds and bucks are attached to these partitions in the same manner as described in the previous article. The lathing is secured to the studs by tying with annealed wire.

111. A partition formed with *Trussit,* a form of expanded metal shown in Fig. 63 (*e*), is shown in Fig. 69. This material fits into a socket consisting of a metal angle, made of expanded

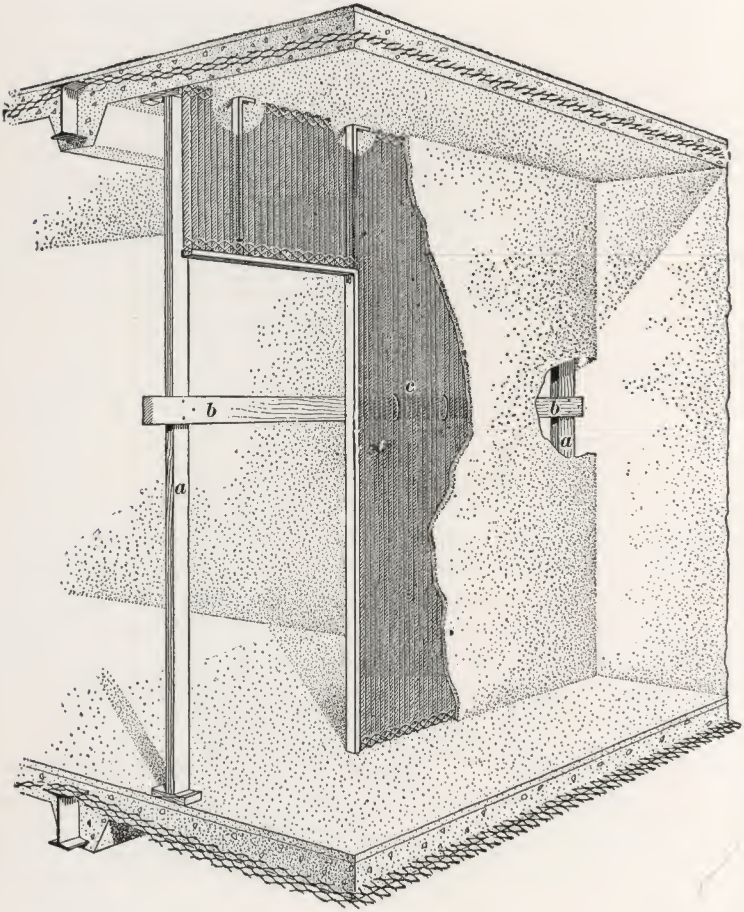


Fig. 69

metal, which is secured to the floor and wired to the Trussit. A similar socket holds it at the ceiling. Door jambs are formed of rolled channels to which wooden bucks are fastened. Grounds are wired or else secured to the Trussit by nailing.

While one side of a partition is being plastered, a simple form of bracing is placed against the other side. This may consist of uprights *a* to which cross-braces *b* are nailed. These cross-braces should be not more than 5 feet apart and the Trussit should be placed with the ribs at right angles to the cross-bracing. The Trussit should be temporarily wired to the bracing, as at *c*. When the plastering has set on one side, the bracing is removed and placed against the plastered side and the opposite side plastered. Ordinarily this partition is made about 2 inches in thickness but by the addition of more coatings of plaster can be made 3½ inches thick.

112. A method of forming a fireproof door jamb in which no wood is used is shown in Fig. 70. A 1½-inch channel stud *a* runs to the ceiling on each side of the door and a 2-inch channel *b* is fastened to it to form a buck. A jamb *c*, of sheet metal,

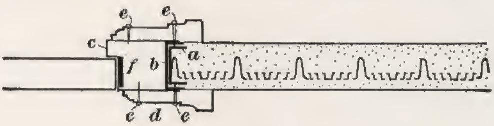


FIG. 70

is fastened to the channel buck and a sheet-metal trim *d* is fastened to the buck and jamb by screws *e*. This holds the trim firmly in place. The jamb is reinforced at the points where the hinges and locks occur by strips of metal *f*. This treatment makes an absolutely incombustible and practically fireproof door jamb and trim.

113. All the solid partitions shown are what are called self-supporting partitions, which do not carry any load besides their own weight.

114. Hollow Partitions.—Hollow fireproof partitions are formed with rolled-steel studding in the form of angles or channels, as shown in Fig. 55, and with sheet-metal studs of shapes shown in Fig. 56. These partitions are generally self-supporting, but, by using I studs and channel sections of sufficient size and thickness, they may be made of sufficient strength to support light loads. The construction of hollow partitions is

practically the same as that of wood-and-plaster partitions except that the studs and lath are of metal.

The studs are secured to the ceiling and floor in a manner similar to that described for the studs in solid partitions.

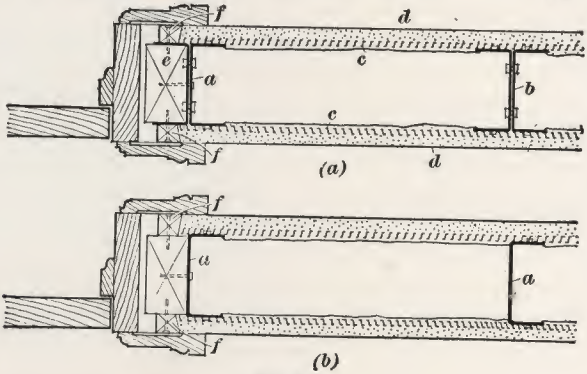


Fig. 71

Grounds are set in between the studs and are secured to them by means of screws or nails. The treatment of jambs for doors and other openings is illustrated in Fig. 71. In (*a*) is shown a sheet-metal **I** stud *a* composed of two channels fastened together. At *b* is an **I** stud, at *c, c* two coverings of metal lath, and at *d, d* the plastering on each side of the partition. The wooden buck is shown at *e*, and plaster grounds at *f*. In (*b*) channel studs are shown at *a* and *a*. The method of constructing partitions with channel studs and with rolled-steel studs is the same as with the **I** studs.

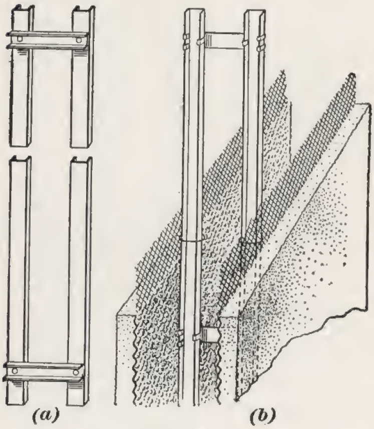


Fig. 72

Studs of the sections shown in Fig. 71, as well as the rolled-steel sections, can be depended upon to support a certain amount of load in proportion to their height and the sizes of the studs. Studding for

hollow partitions is sometimes built up of light steel sections where the partition is required to be thick. A rolled-steel studding of this kind is shown in Fig. 72 (*a*). A similar form of studding made of sheet metal is shown in Fig. 72 (*b*).

FURRING

115. Furring is a framework of steel or wood designed to support lath and plastering; the term is also applied to the materials used for the purpose. Furring is usually attached to the structural parts of a building, such as walls, floors, partitions, etc., and does not, as a rule, add to the strength of the building. Furring is applied to masonry walls to hold the lathing and plastering away from the surface of the wall so as to form an air space to prevent the passage of moisture. Furring of metal or wood is also used in making false constructions of plaster, such as cornices, coves, domes, beams, and other architectural or constructional forms. In the following discussion, metal furring only will be considered.

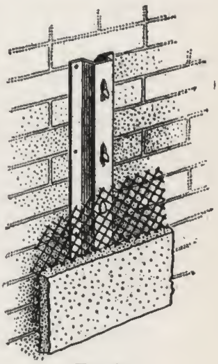


FIG. 73

116. Furring Walls.—Walls are furred to form an air space between the face of a masonry wall and the plastering to prevent the passage of moisture, which sometimes penetrates masonry walls. A space of an inch or so is sufficient. Metal furring may consist of separate pieces of metal which are attached to the surface of the wall and to which the metal lath is attached, or may be formed in the sheet of metal lath. The separate furring may be of the same forms as the metal studding that has been described, namely channels, angles, etc., or of forms especially designed for the purpose. In Fig. 73 is shown a sheet-steel furring which is nailed to the wall through the holes shown on the sides and which holds the metal lath by means of prongs.

In Fig. 74 is shown a rolled-steel channel used as a furring. This channel is secured to the wall by means of large staples that are driven into the joints of the brickwork. The flange of the channel has holes punched in it through which wires are placed to secure the lath.

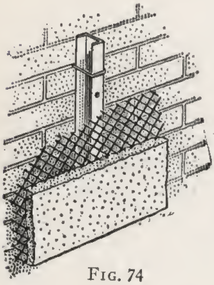


Fig. 74

A combination furring and lath is shown in Fig. 75 in which the **V** stiffeners *a* act as furring strips and hold the lath *b* away from the wall. The metal lath and the stiffeners are stamped out of the sheet at the same time.

117. Furring Flat Ceilings.—Flat metal-lath ceilings are made of either of two forms of construction, the one requiring a framework to which the lath is applied and the other being formed of a lath

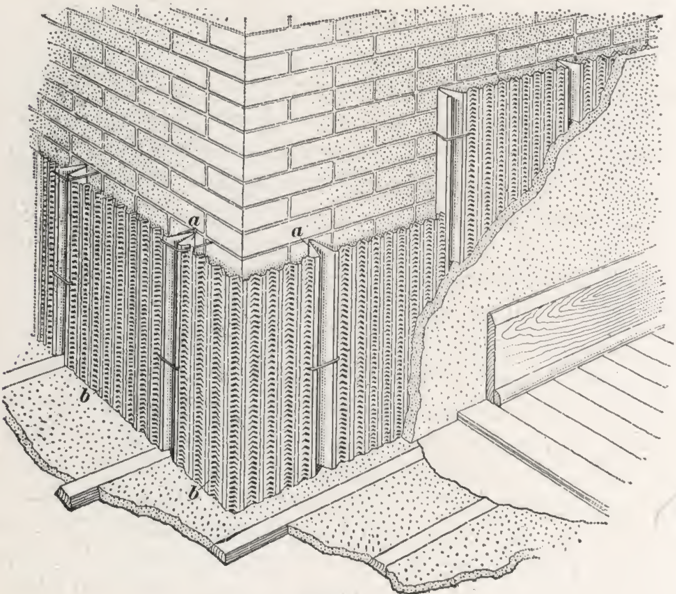


Fig. 75

that is reinforced and is sufficiently strong to span between the structural beams of the ceiling or between suspended beams.

The forms of lath used for these two classes are similar to those used for partitions and furred walls.

118. In Fig. 76 is shown a simple form of construction that is typical for all metal-lath suspended ceilings that have a framework. The suspension rods *a* have one end formed to fit the lower flange of the steel beam, and clips *b* are attached to these rods to form secure connections with the beams. The lower ends of the rods are bolted to angle irons *c*, and channel irons *d* are secured to these angles by means of wire clips *e* specially made for this purpose. In this illustration, expanded-

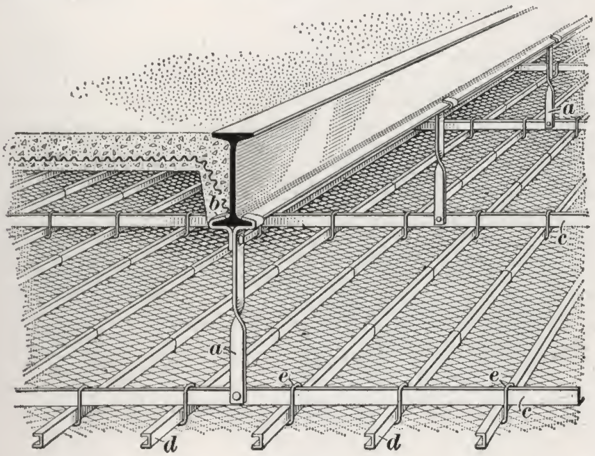


FIG. 76

metal lath is shown and this is tied to the channels by means of wires. The channels *d* are 1 inch in size and are spaced 12 inches on centers. The angles *c* are $1\frac{1}{2}$ in.$\times 1\frac{1}{2}$ in.$\times \frac{3}{16}$ in. and the suspension rods *a* are 1 in.$\times \frac{3}{16}$ in. The angle irons are usually spaced about 4 feet apart.

119. Metal lath having ribs or other forms of reinforcement is attached to the bottoms of the beams, or suspended below the beams, and either the channels or angles, or both, may be omitted.

Where this form of lath is placed directly under the lower flange of the beam, any form of fastening may be used that

will have the required strength and make the connection rigid. As a rule, each manufacturer produces a special form of clip for attaching his style of lath to the beams. For a suspended ceiling, however, suspension rods similar to those previously described will be required, also angles of similar size and spacing, the intermediate channels, however, being replaced by the

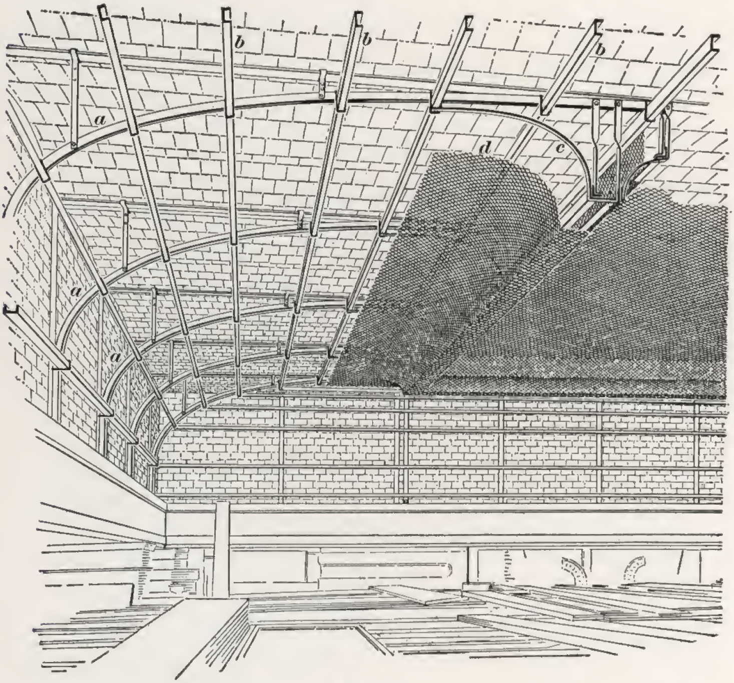


Fig. 77

ribs in the lath. When applying the lath to the angles, each rib of the lath should be strongly fastened to the angles.

120. Furring Curved Ceilings.—Metal-lath ceilings are sometimes formed with curved surfaces. The principles involved in the construction of all curved ceilings are practically the same, consequently only one illustration will be given.

In Fig. 77 is shown a ceiling having a large curved surface at the intersection with the side walls, which is called a cove.

Between this cove and the flat ceiling is a suspended frame and metal-lath covering that is to receive an ornamental plaster beam.

The curved bars *a* are usually formed of steel angles and their size will depend upon the size of the curved surface they form and the load of plaster they are required to carry. These angles are securely fastened to the wall and ceiling construction. To these angles are fastened the regular channels *b*, which are usually 1 inch in size. In this illustration, at *c* is shown a bracket formed to receive the metal lath for a sec-

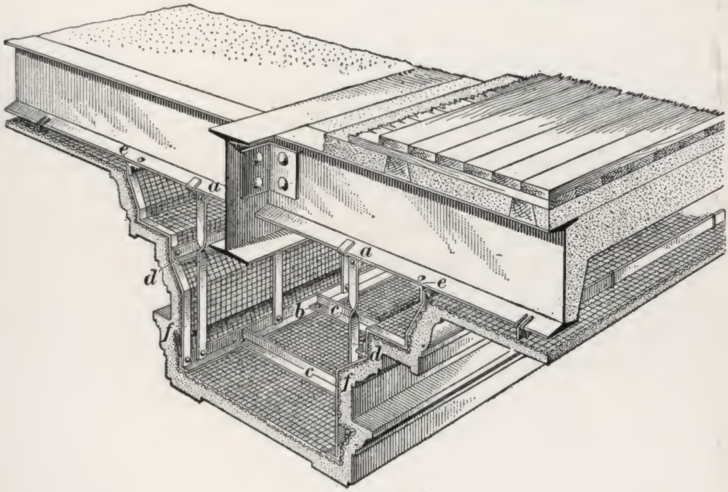


FIG. 78

ondary plaster cove; and at *d* is shown the metal-lath covering over the framing of the cove which is approximately of the form and size required for the finished work.

121. Furring for Cornices and Beams.—Metal furring and metal lath are used in constructing large-sized cornices and false beams in fireproof buildings. In furring these features, the frame is made to conform as nearly as possible to the profile of the feature so that the plastering will not be unnecessarily thick.

The frame is made of plain flat bars, angles, or channels that are securely bolted together and secured to the wall or to steel

beams. Metal lath should be plain expanded metal or metal fabric of light weight so that it may be easily bent around the frame into the required shape.

122. Fig. 78 shows a false beam with a cornice on each side. The furring and metal lath are also illustrated. The hangers *a* are similar to those shown for the hung ceiling in Fig. 76. These hangers are connected to horizontal angle bars, one of which is shown at *b*, Fig. 78. This angle and a similar one on the other side of the beam are connected together and braced by means of crosspieces *c*. Other angle bars are shown at *d* and *e*. At *f, f* are shown flat bars that are formed to an approximate outline of the cornice and which are connected with the horizontal angles to form a framework that is strong and rigid. It will be noted that the angle bars at *e* are connected directly to the structural beam of the ceiling.

PLASTERING

123. Purpose of Plastering.—The object of plastering, from the standpoint of fireproofing, is to protect metal from the action of fire. In the case of protecting columns, beams, partitions, etc. from fire, the furring and lath are attached to these various members and the lath is embedded in a good coating of plaster. The value of this coating depends upon the quality of the plastering. Cement plaster made of 1 part Portland cement, $\frac{1}{10}$ of a part of hydrated lime, and $2\frac{1}{2}$ parts of sand has a great fire-resisting value and affords the best protection that can be obtained by using plaster. Patent plasters, of which the base is gypsum, have not the fireproofing value of cement plaster. They are, however, good fire retardants and afford considerable protection to metal lath, furring, and steel studding enclosed by them.

124. Method of Applying Plaster.—The method of applying plaster to metal lath is described in another Section. The construction of the solid partition, however, is somewhat different. In this construction, the plaster is first applied to

one side of the metal lath and when this plaster has set the other side is plastered. This process is repeated until the full thickness of the partition has been obtained.

FIREPROOFING WITH PLASTER BLOCKS

125. Plaster Blocks.—Plaster blocks, that is, blocks made of plaster of Paris mixed with various substances, such as cinders, coconut fiber, asbestos, or wood chips, are sometimes used both for column coverings and for partitions. Notwithstanding their value as heat insulators, they are softened by the heat, and easily washed away by a stream of water from a hose, and the softening and washing will penetrate deeper than with other materials.

In small buildings or buildings in which the highest degree of fireproofing is not essential, plaster blocks can be used advantageously for partitions and on account of their cheapness prove very satisfactory for this purpose. Plaster blocks can be cut with a saw and possess considerable holding power for nails. They are light in weight and when plastered on both sides will offer sufficient resistance to heat and flame to warrant their use in ordinary buildings.

MISCELLANEOUS FIREPROOFING MATERIALS

126. In the fireproofing of buildings, the aim is not only to prevent a collapse of the building through failure of some of the steel supporting members, but to confine a fire that might originate in one part so it will not spread to other parts of the building. The fireproofing should also be designed to prevent the fire from passing through door or window openings to adjoining buildings and from entering the building from adjacent burning buildings. This has led to the manufacture of new materials and the using of old materials in such a way that they will fireproof all openings. Some of these new materials will next be described.

127. Fireproof Wood.—Among the fireproof materials used for trim in buildings and approved by most of the building codes, is fireproof wood. This is ordinary lumber which by a special process has had the resin, oils, and other inflammable materials abstracted, leaving only the cellular tissue of the wood. It is then impregnated with chemicals and covered with a fireproof paint. Wood so treated will glow but not flame, and may be considered fireproof. Closely allied to fireproof wood protected by fireproof paint is a process of treating wood to give it the appearance of metal. This consists of electrically depositing a layer of copper on the exposed surfaces of the wood, which is then said to be *copperized.*

128. Metal-Covered Wooden Trim.—There are several makes of wooden interior trim on the market, all of which are made fireproof by covering the wood with sheet metal of some kind. Metal-covered trim can be had that is covered with iron, copper, bronze, or any other metal or alloy. Some of the finishes are crude in appearance, while others are very attractive.

Under the trade name of *Kalamein Iron,* trim may be had that is covered with sheet steel, the surface of which has been specially treated with a coating of tin and lead in much the same manner that galvanizing is applied to iron or steel.

129. Metal-Covered Window Frames and Sashes. Metal-covered window frames and sashes are likewise made and fill an important place in fireproof construction. On account of the sash and frame being exposed to the elements it is desirable to cover them with bronze or some other non-corrosive metal that will not deteriorate.

130. Hollow Metal Doors and Trim.—In hollow metal doors and trim is to be found a high type, artistically and structurally, of fireproofing. Unlike the metal-covered doors and trim, hollow metal doors have no core of wood or other material with the exception of the material placed between the two faces of the doors to back up the sheet metal and deaden the sound.

Hollow metal doors, trim, sashes, windows, etc., are enameled and rubbed to a dull gloss and used in the finest of buildings.

131. Cement Trim.—In many fireproof buildings the floors and base are made of cement or some similar plastic material and the door and window trim is made of Keene cement and finished in imitation of woodwork, thus providing a finish that is cheaper than metal and which is also fireproof.

132. Wire Glass.—The manufacture of glass with a wire mesh embedded therein makes it possible to secure protection from fire through window openings without disfiguring the building by the use of fireproof shutters. This form of glass is made by rolling the wire into the plastic glass at a temperature which causes it to adhere to the wire. Should the glass become cracked or broken during the course of a fire, the wire mesh will hold it in place and prevent the spread of the flames through it.

133. Steel Shutters.—Another method of guarding windows and also doors is by the use of shutters, of which there are two types, the steel rolling shutter and the tin-covered shutter. The steel rolling window shutters are illustrated in Fig. 79 at *a*, and a door shutter at *b*. These shutters are constructed so that they can be raised or lowered by hand or so that they will act automatically in case of fire. The automatic action is produced by the use of links or plugs of fusible metal, as described later for tin-clad doors, and springs. Such automatic shutters may be used on interior openings as well as on exterior ones. Thus, in closing openings to elevators and stair halls these shutters are very useful in preventing the spread of fire. It is especially necessary to protect openings that are close to adjacent buildings that are dangerously inflammable.

134. Tin-Covered Shutters.—The tin-covered shutters are wooden shutters built up of two or three layers of $\frac{7}{8}$-inch boards, covered with sheets of tin that are put together with nailed lock joints and without the use of solder. The wood is protected from burning by the tin, and the stiffness of the wood keeps the shutters in shape under the action of a severe fire.

135. Of the tin-covered and the steel shutters, the tin-covered wooden shutters are the more effective. Under the action of the heat the steel shutters will warp and transmit

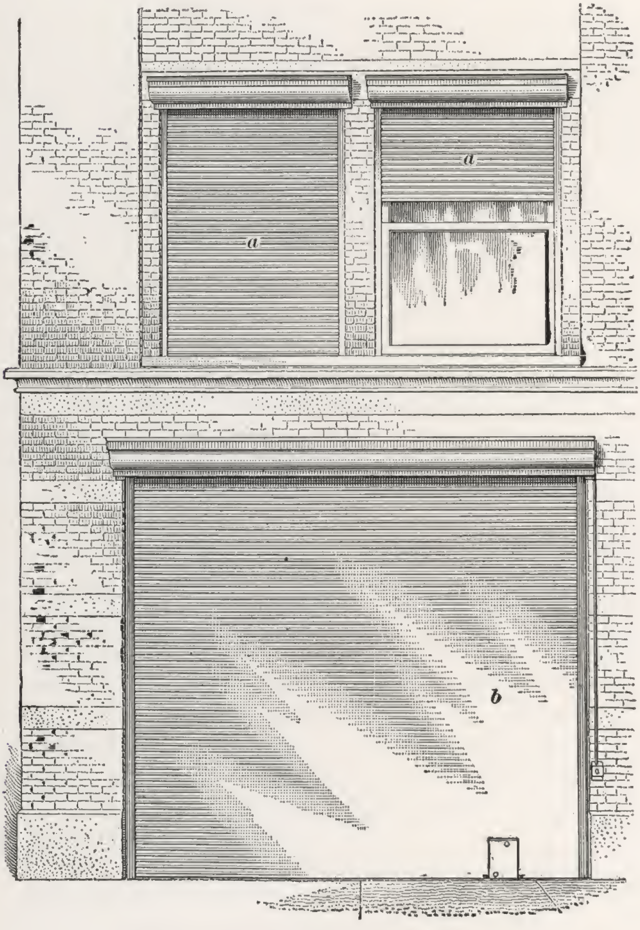


Fig. 79

heat very rapidly. Tin-covered wooden shutters, on the other hand, transmit heat very poorly, warp but little, and are the best protection against outside fire, so long as they are closed. The great weakness of shutters lies in the fact that they may

be open when a fire is raging and consequently afford no protection whatsoever.

136. Tin-Clad Doors.—Tin-clad doors are used in closing openings in masonry walls between various sections of a large building. Usually they are made to act automatically, that is, they are built so that in case of a fire reaching the opening a fusible link or plug of metal will be melted and the door will

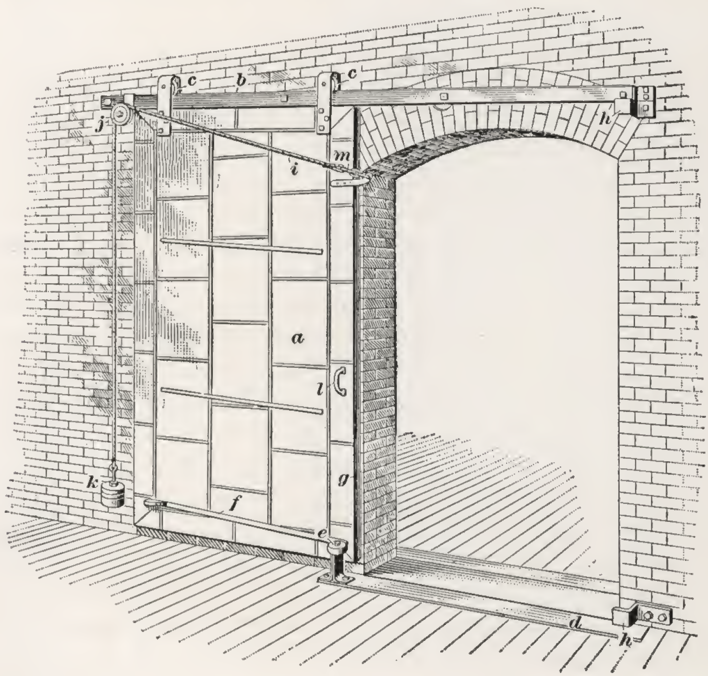


Fig. 80

close automatically. An automatic tin-clad door is shown in Fig. 80. The door itself is shown at *a*. This door shows the tin covering with the locked joints between the tin plates. The door is hung on the inclined track *b*. This track is a flat bar fastened to the wall by bolts that extend entirely through the wall. Between the wall and the bar are washers that keep the track away from the wall so that the hangers *c* can run freely along the track. These hangers are bolted to the door, the bolts

extending through the door. The track being inclined, the door will naturally close and stay closed if it is not held open by the devices shown. When open, the door is in a higher position, due to the slope of the track. When it is closed, however, the bottom of the door touches the iron sill *d*, which must extend beyond the face and edges of the door and must be secured firmly to the brick walls. In case of the floor burning away, this sill must remain in place. The bottom of the door is kept from swinging away from the wall by the roller *e*, which is also bolted to the wall or sill. Secured to the door is a strip of iron *f* upon which this roller presses. When the door is closed, the edge *g* enters the bumpers *h*, which hold it close against the wall, while the roller similarly holds the other edge. A sash cord *i* extends around the pulley *j* and is attached to the weight *k*. This holds the door open. The door is closed by simply pulling it to by means of the handle *l*. A piece of metal that will melt at a very low temperature, called a fusible link, is shown at *m*. If the door is left open and a fire occurs on one side of the wall, when the flame, or even intense heat, reaches this link, it will melt. This will release the cord *i* and the weight *k* will drop. The door will then of its own weight roll down the track and close. A door such as the one just described will resist a tremendous fire. These doors should always bear the Underwriters' Laboratories label indicating that they are approved by the National Board of Fire Underwriters and when possible should always be placed on both sides of a wall.

There are many different patterns and makes of these doors and appliances. There are also various types of doors that can be used, such as double sliding doors, swinging doors, and doors that slide upwards. These various types are described in booklets issued by the National Board of Fire Underwriters. They are also made and sold by various concerns that make them in accordance with the rules of the National Board.

137. Protecting Openings to Stairways and Elevator Shafts.—In the fireproofing of buildings it is of special importance to protect all approaches to elevator shafts and

stair wells, so that fire cannot reach them. This is done by enclosing the shafts and wells in fireproof walls and by having the openings protected by fireproof doors. During a fire, the stairways and elevator shafts, if left exposed, will act as flues, giving draft to the fire, shutting off all escape from the upper floors, and allowing the flames to spread to all parts of the building. Whenever there are window openings, either to stair wells or elevator shafts, they should have wire glass set in fireproof frames to protect them from fire from without.

FIRE-EXTINGUISHING METHODS

138. Portable Fire Extinguishers.—Fire extinguishers, as they are generally called, are portable devices that contain chemicals of such a character that when these chemicals are discharged and spread over a flame they will form a gas that shuts out the air and thus extinguishes the fire.

139. Buildings that contain valuable materials or goods are protected against loss by fire by automatic sprinkler systems or by standpipe systems. These equipments become a permanent part of the building, and a brief description of their operation will be given.

140. Automatic Sprinkler Systems.—As the name implies, automatic sprinkler systems are automatic in their operation and consist of outlets, in or near the ceiling, which are placed at regular intervals and equipped with what are known as *sprinkler heads*. The heads are provided with fusible links so designed that they will melt at a low temperature such as may be produced by a fire at its beginning. The melting of the fuses opens the heads, and water is sprayed over a given area, the heads being so located that the entire floor of the building is thus provided with this protection. The water is supplied either from an open tank, which is placed on top of the building to obtain a suitable pressure by gravity, or from a closed steel tank which has had air pumped into it to secure the necessary pressure of water. The tanks are made with a

capacity only sufficient to supply water for a limited period of time pending the arrival of the fire engines.

141. Standpipe System.—Another form of fire protection is the *standpipe system.* This consists of a vertical pipe, usually located in a stair well, which extends from the basement to the top story of the building. The bottom of this pipe is connected with the city water main in the street and at each story is a branch pipe, a controlling valve, and a hose, the latter being placed on a reel of some form. In case of fire the hose is removed from the reel, one end of the hose being connected with the standpipe, the valve is opened, and water is supplied directly from the city water main to extinguish the fire. In high buildings, the city water pressure is not always sufficient to supply water to the upper stories, and auxiliary pumps or tanks are often required to make the standpipe system operative for these stories.

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